STA-3/4 2-D Hydraulic Modeling (Linked Cells Model) Final Report

Science and Engineering Support Service (SESS) Contract No. C-15988-WO04-05

South Florida Water Management District

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STA Hydraulic Modeling Contract C-15988-WO04-05 (SESS Contract)

1. Introduction

STA-3/4 is a primary component of the Everglades Construction Project mandated by the 1994 Everglades Forever Act (Section 373.4592, Florida Statutes). STA-3/4 is located immediately east (and north) of the Holey Land Wildlife Management Area and north of Water Conservation Area 3A (WCA-3A) and west of Highway US 27 (Figure 1). It receives stormwater runoff from the S-2/7, S-3/8, S-236 and C-139 Basins in the Everglades Agricultural Area and Lake Okeechobee and provides a nominal treatment area of 16,543 acres. It is one of the largest constructed wetlands in the world.

In the original design, STA-3/4 consisted of five treatment cells (Cells 1A, 1B, 2A, 2B and 3) and three flow ways. Cells 1A and 1B are the eastern flow path. Cells 2A and 2B are the central flow way and Cell 3 is the western flow path of STA-3/4 (Figure 2).

Two-Dimensional (2-D) hydraulic models have been previously developed for single cells of STA-3/4 under steady flow conditions (Burns & McDonnell, 2000). That modeling work was conducted for design purposes. The steady state 2-D model built by Burns & McDonnell was not calibrated to any historic data as it obviously did not exist and the Manning's n values were assumed.

The current project work is an attempt to develop a new 2-D linked Cells model for STA-3/4 with observed stage and flow data and updated project features, and to perform transient and steady flow simulations of the STA-3/4 hydraulics. The new 2-D model was calibrated and validated with historic stage data.

The calibrated model is then used to simulate steady flow scenarios for STA-3/4 for Low, Design and High Flow Conditions for the STA-3/4 Enhanced configuration. The majority of present tasks are spelled out under Task 3 of the contract scope of work, precisely under Subtasks 3.1: STA-3/4 Linked Cells Model and 3.2: STA-3/4 Draft Report.

This final report (Task 3.3) summarizes major results obtained in the modeling work for the Subtask 3.1 as well as Subtask 3.2 of this project. Comments received from the District on the draft report (Subtask 3.2) have been incorporated into this report.

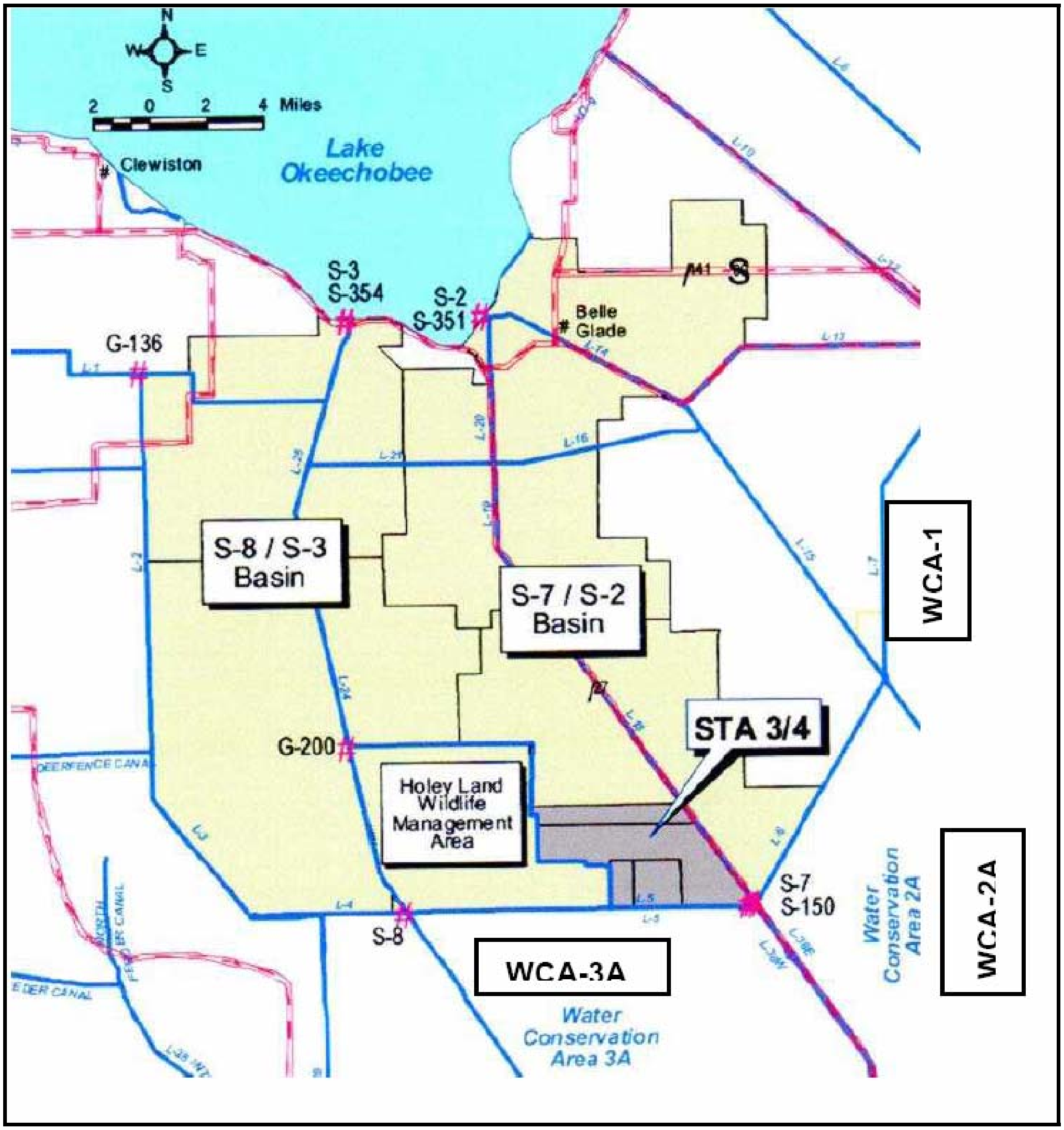

Figure 1: Location of STA-3/4

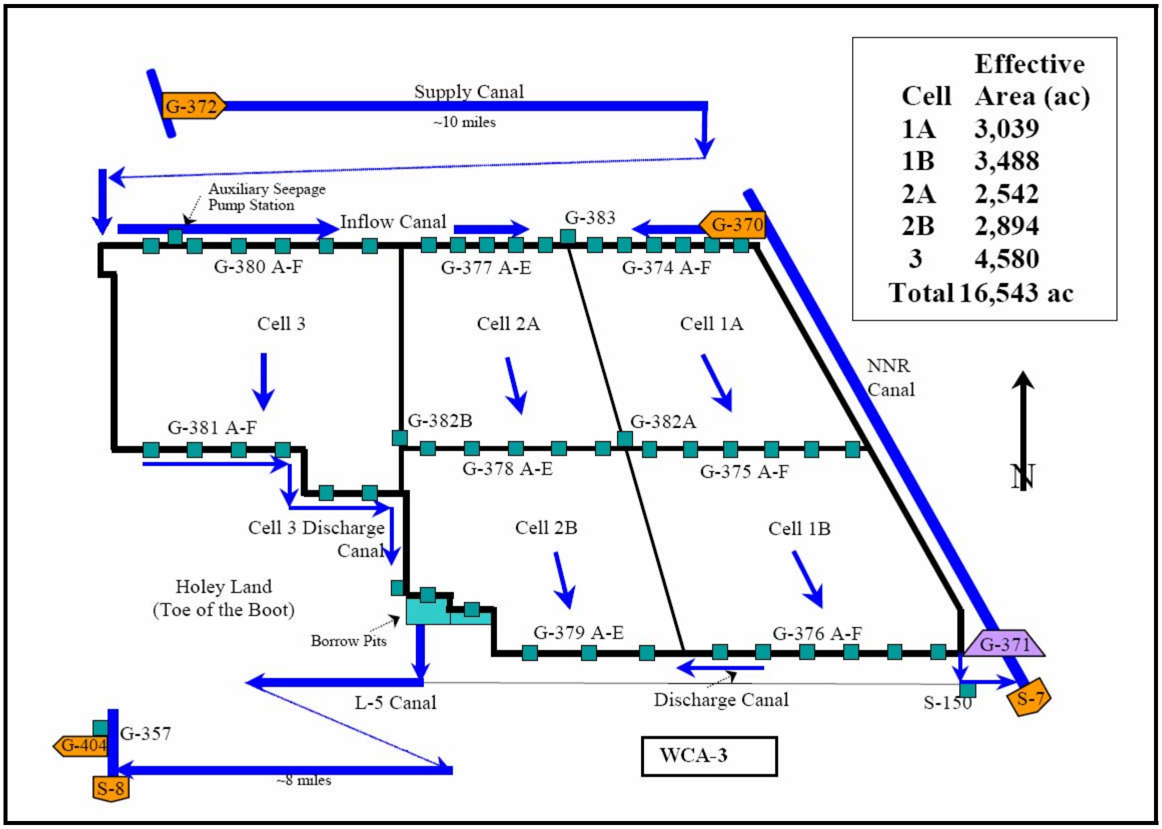

Figure 2: Current Schematic Layout of STA-3/4

2. Modeling Purpose and Objective

As stated in the scope of work, current modeling work is the update of previous STA-3/4 model developed by Burns & McDonnell during the STA-3/4 detailed design. This task is described in the Long-Term Plan for Achieving Water Quality Goals as "Update and Maintenance of Hydraulic Models [Bc82(5)]":

"Available hydraulic models of the existing and under construction STAs vary widely in degree of detail. Detailed hydraulic models are needed to predict and control changes in flow distribution as the STAs mature and change with time. The models should be regularly updated and calibrated as revised information on the character and extent of vegetative communities is received."

Specifically, for STA-3/4, the tasks to be accomplished are: (1) develop a linked cells 2-D hydraulic model by using information from the single cell models developed by Burns & McDonnell (2000); (2) perform steady state flow simulations for Design Peak Flow, Low Flow and High Flow conditions; (3) provide any conclusions and/or recommendations for operational decision making resulted from the modeling exercise.

3. Model Setup

The FESWMS/FLO2DH computer program was selected by the District as the modeling tool for the current hydrodynamic modeling of STAs. The Flo2DH model engine is part of the Federal Highway Administration's Finite Element Surface-water Modeling System (FESWMS). It is a public domain model code but the Graphic User Interface (GUI) through the Surface Water Modeling System (SMS) is commercial software. FLO2DH simulates two-dimensional depth averaged hydrodynamic flows of surface water bodies using the finite element method. Additional information about the theoretical background of the model code, its numerical method, input and output data requirement can be found in the User's Manual for FLO2DH 3.0 (Froehlich, 2002).

3.1 Conceptual Model of STA-3/4 Hydraulics

As can be seen in Figure 2, STA-3/4 receives stormwater runoff from the Miami Canal via Pumping Station G-372 and the North New River Canal via Pumping Station G-370.

From G-372, inflow from the Miami Canal is carried in the Supply and Inflow Canals along the northwestern boundary of STA-3/4. It is then distributed to Cell 2A and Cell 3 (central and western flow-ways) through Inflow Structures G-377 A-E and G-380 A-F. From G-370, inflow from the North New River Canal enters the eastern part of the Inflow Canal and is discharged into Cell 1A (eastern flow-way) through Inflow Structures G-374 A-F.

Structure G-371 located in the North New River Canal is normally closed but it can be opened to pass water from the North New River Canal to downstream areas if needed. Inflow structure G-383 is located in the Inflow Canal and is normally closed to separate inflows from the North New River Canal and the Miami Canal. It can be operated to balance flow differences in the three flow-ways. Interior control structures G-382 A and B have similar functionality and are normally closed. They can provide transfer of water between cells under low flow conditions to prevent cell dry-out.

Interior flow structures G-375 A-F and G-378 A-E convey water from upstream cells to the downstream cells. Outflow structures G-376, G-379 and G-381 regulate discharge of treated water from STA-3/4.

The model domain stops at the Discharge Canals on the south. The Seepage Collection Canal that runs along the northern boundaries of STA-3/4 is not included in the model. Pumping stations (G-370 and G-372) cannot be directly simulated by FLO2DH. They are considered as point source/sink at the ends of the Inflow Canal in the model.

3.2 Topography

Ground surface elevations were obtained from previous model files (Burns & McDonnell, 2000) and descriptions of the canals in the STA-3/4 Operation Plan

(SFWMD, 2004). Updated topographical survey data have not been collected for this STA; therefore, they were not available for this modeling project. The variation in ground surface elevations in STA-3/4 is small compared to its large surface area. In the marsh areas, the ground surface elevations range from 9.0 ft NGVD to 10.8 ft NGVD, as shown in Figure 3.

There are several remnant transverse ditches in the upstream cells. A bottom elevation of -1.5 ft NGVD was assumed for these remnant ditches based on the Burns & McDonnell data.

The Inflow Canal has an invert elevation of -5.5 ft NGVD. The Discharge Canal has a bottom elevation of -7.0 ft NGVD and the Cell 3 Discharge Canal has a bottom elevation between -5.0 and -6.0 ft NGVD. The borrow pits were included.

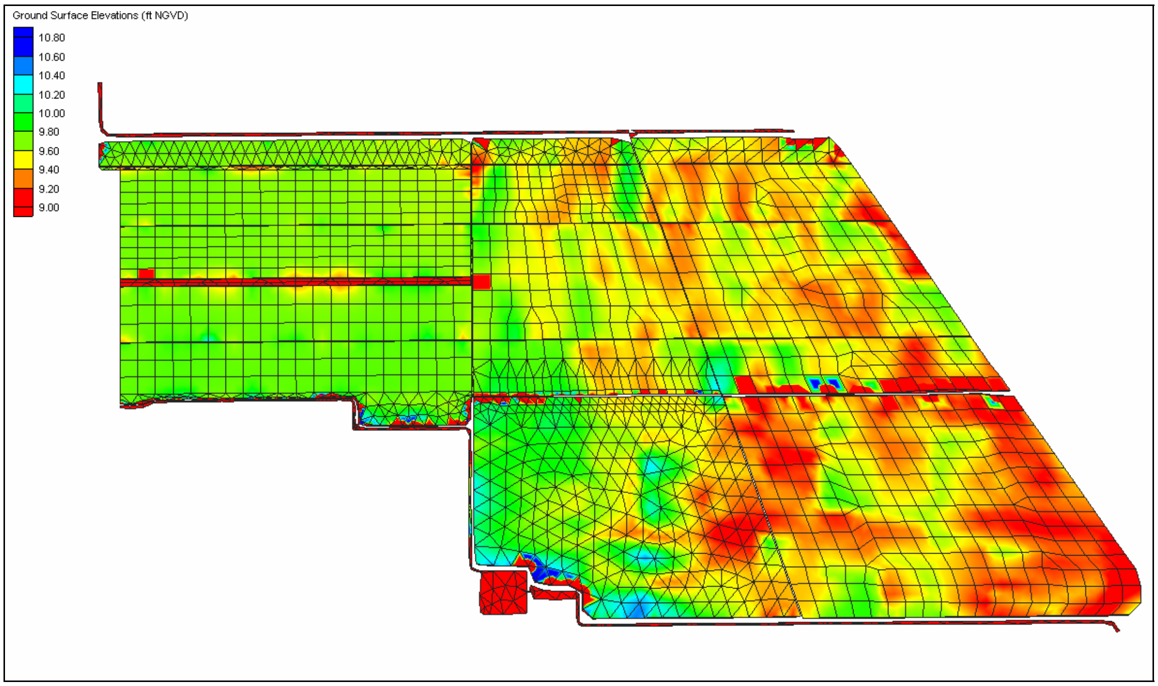

Figure 3: STA-3/4 Ground Surface Elevations (Marsh areas)

3.3 Vegetation

Bottom resistance to flow is represented by the friction coefficient (Manning's roughness coefficient (n value)) in FLO2DH and every finite element must be assigned a material type. The material type for flow resistance purposes in a constructed wetland such as STA-3/4 is the combination of bottom material (bare soil) and vegetative cover.

Uniform emergent vegetation coverage was assumed during STA-3/4 design. The vegetation has since changed gradually. Cell 2B is now considered as Submerged Aquatic Vegetation (SAV) dominant. In the enhanced configuration, all downstream treatment cells will be converted to SAV dominant. Accordingly, different vegetation distributions were applied in model simulations for model calibration and flow scenarios.

All canals and interior remnant ditches were assumed to be free of vegetation.

3.4 Boundary Conditions

There are two types of external boundaries in FLO2DH: open boundary and closed boundary. For STA-3/4, inflow and outflow structures are open boundaries of the model domain. Specified stage boundary is applied at the end of the downstream Discharge Canal. Water Flows into STA-3/4 are through the two ends of the Inflow Canal via pumping by G-370 and G-372. Specified flow or stage boundary conditions are applied at the ends of the Inflow Canal.

The Inflow Canal, each cell of STA-3/4 and the Discharge Canals are hydraulically connected through flow structures defined as culverts in the models.

No-flow boundary condition is applied to the normal direction of all interior and perimeter levees. Semi-slip boundary condition is assumed along levees. This means that water can flow along the levee with wall friction.

Distributed source or sink terms include direct rainfall, evapotranspiration (ET) and seepage losses. FLO2DH cannot directly handle distributed source/sink terms such as rainfall/ET. In the simulations of Low Flow and High Flow Conditions, rainfall, ET or seepage losses are accounted for as point source/sink distributed over certain numbers of nodes.

3.5 Finite Element Mesh

The whole flow domain was divided into triangular elements and quadrilateral elements of different sizes (Figure 3). Since each cell of STA-3/4 is linked together in the linked cells model and transient simulations are performed, the number of finite elements was decreased to reduce computation time. Even after this change, one model calibration run can still take several hours to complete.

4. Model calibration and verification

4.1 Model Calibration Target

The STA-3/4 linked cells model was calibrated to Cell 1 and Cell 2 historic stages. Cell 1 and Cell 2 historic flow and stage data are available from January, 2005 to present. Cell 3 was off-line during this time period and Cell 3 had no interior stage observation. Because G-383 was always closed during this time period, water flows in Cell 1 and Cell 2 have no direct hydraulic connection. The interior flow structures G-375 A-F and G-378 A-E tailwater and headwater levels are the major calibration target. The tailwater levels of the inflow structures and the headwater levels of the outflow structures are mostly affected by the boundary conditions. They are also valid calibration targets.

The time period for model calibration is 4/20/2005 to 4/30/2005; and 4/30/2005 to 5/10/2005 for model validation. This is based on the historical storm events and gate operation. Figures 4 and 5 show observed gate openings for outflow structures G-376 and G-379. As the model cannot simulate gate operation, storm events with constant gate opening are preferred.

Model parameters were adjusted during the model calibration period for the best history matching. The calibrated parameters were then used to make model predictions during model validation period.

4.2 Boundary Conditions

During this modeling study, it was learned that the District is in the process of implementing new flow rating equations for STA-3/4 structures. STA-3/4 flow data in DBHYDRO has only been partially updated with new flow equations; and additional STA-3/4 structure flow rating is still under development. In view of the fact that STA-3/4 historical flow data will be updated in the near future, it was decided that observed water levels would be used as the upstream boundary conditions instead of specified flow rates. All culvert parameters are current values obtained from DBHYDRO and default values in FLO2DH.

The use of specified stages instead of specified flows as the upstream boundary conditions may have some impact on the model calibration results. However, previous model calibration results based on both specified stage/flow upstream boundary conditions for STA-6 in a previous modeling study (Sutron Corporation, 2004) were compared and the difference in model results was negligible. The selected time periods have active structure flows (gates are opened).

Selecting the proper initial condition is another important issue in model setup. First, simulations were conducted to closely match water levels at the beginning of model calibration and validation. Then, these simulation results were used as the initial conditions for model calibration runs.

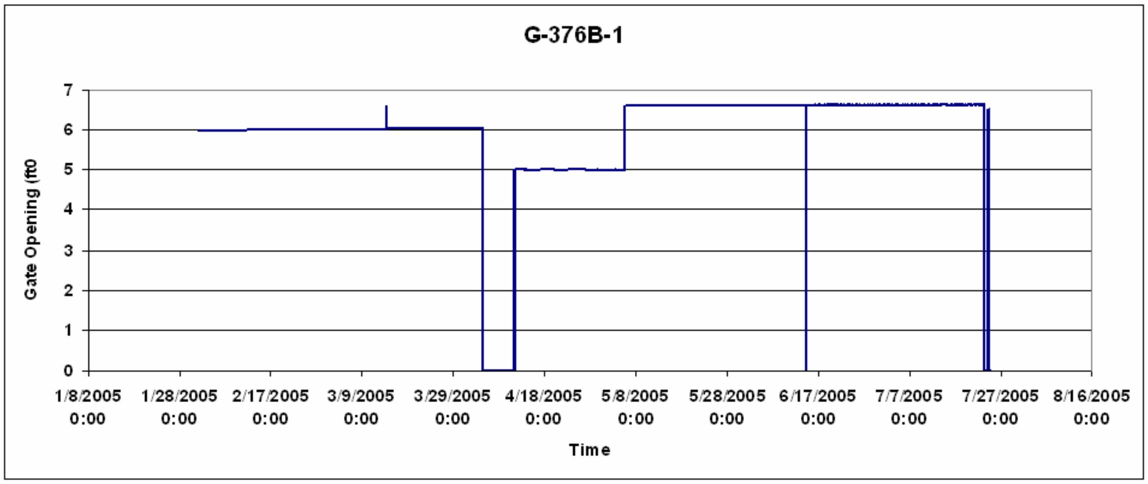

Figure 4: Gate Opening (G-376, Cell 1 outflow structure)

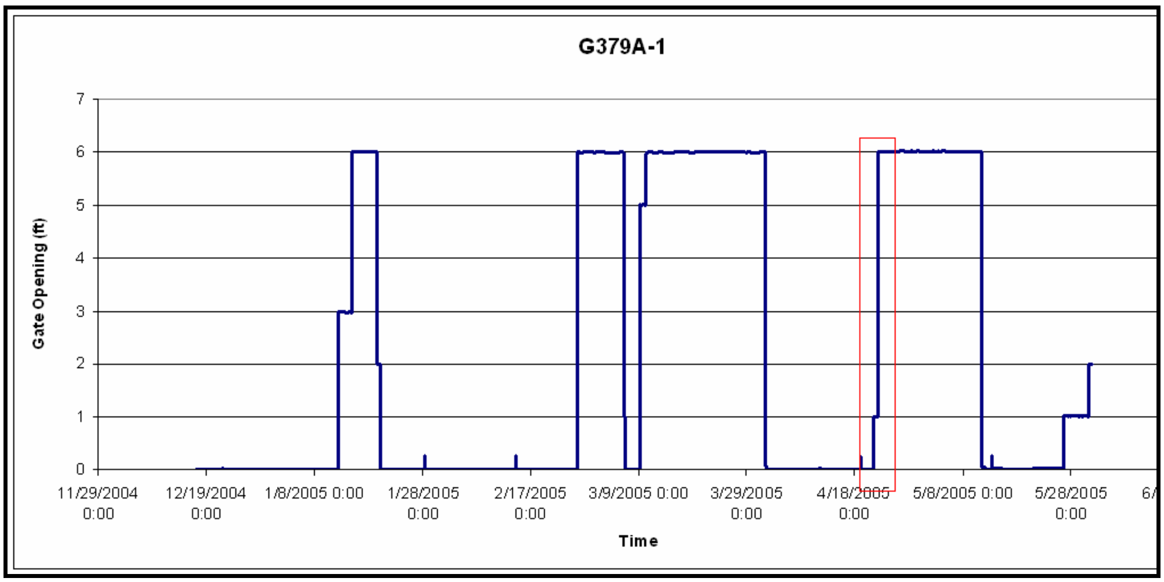

Figure 5: Gate Opening (G-379, Cell 2 outflow structure; the red box shows gate is closed at the first 36 hours of model calibration)

For model calibration and validation, model setup used current vegetation coverage. Vegetation in Cell 1A and 1B were assumed to be emergent cattail dominant under current condition. Cell 2B was set as SAV dominant based on information in the STA-3/4 Operation Plan. The PSTA Demonstration Project site (about 400 acres) in Cell 2B was not explicitly simulated in this current modeling effort.

During model simulations, no flow was routed into Cell 3. From the Inflow Canal, water flows into Cell 1A and Cell 2A (Figure 6). Locations of stage monitoring stations for STA-3/4 are shown in Figure 7.

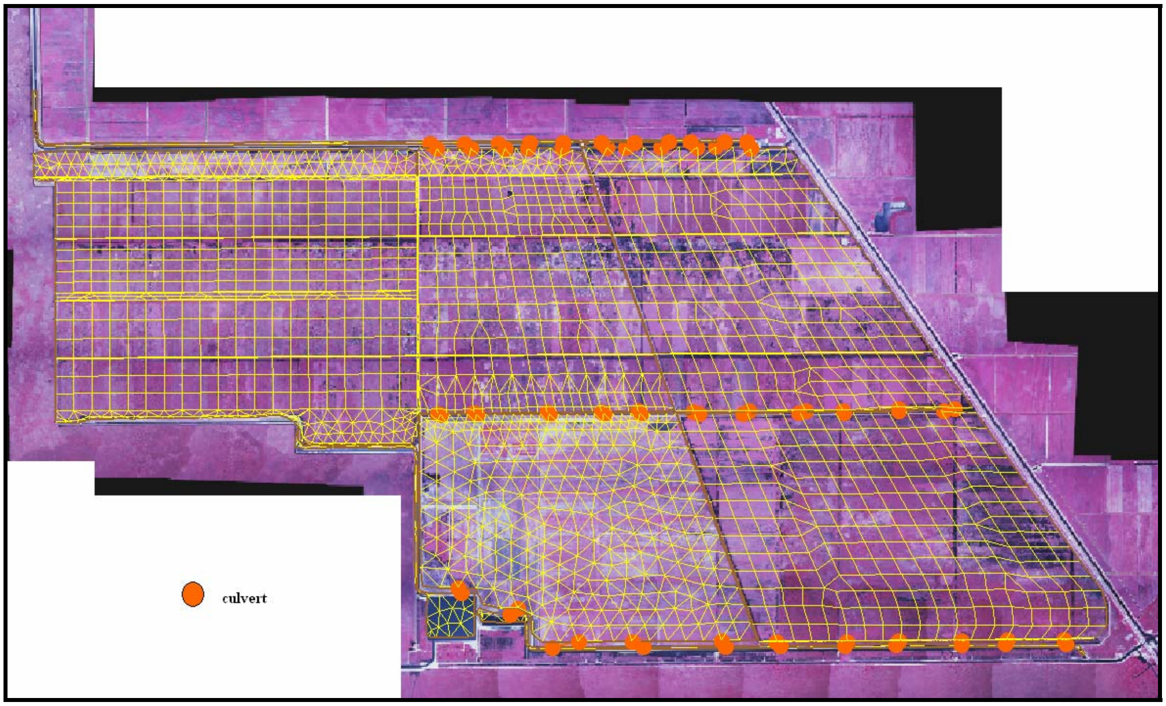

Figure 6: Model Layout for Calibration and Validation

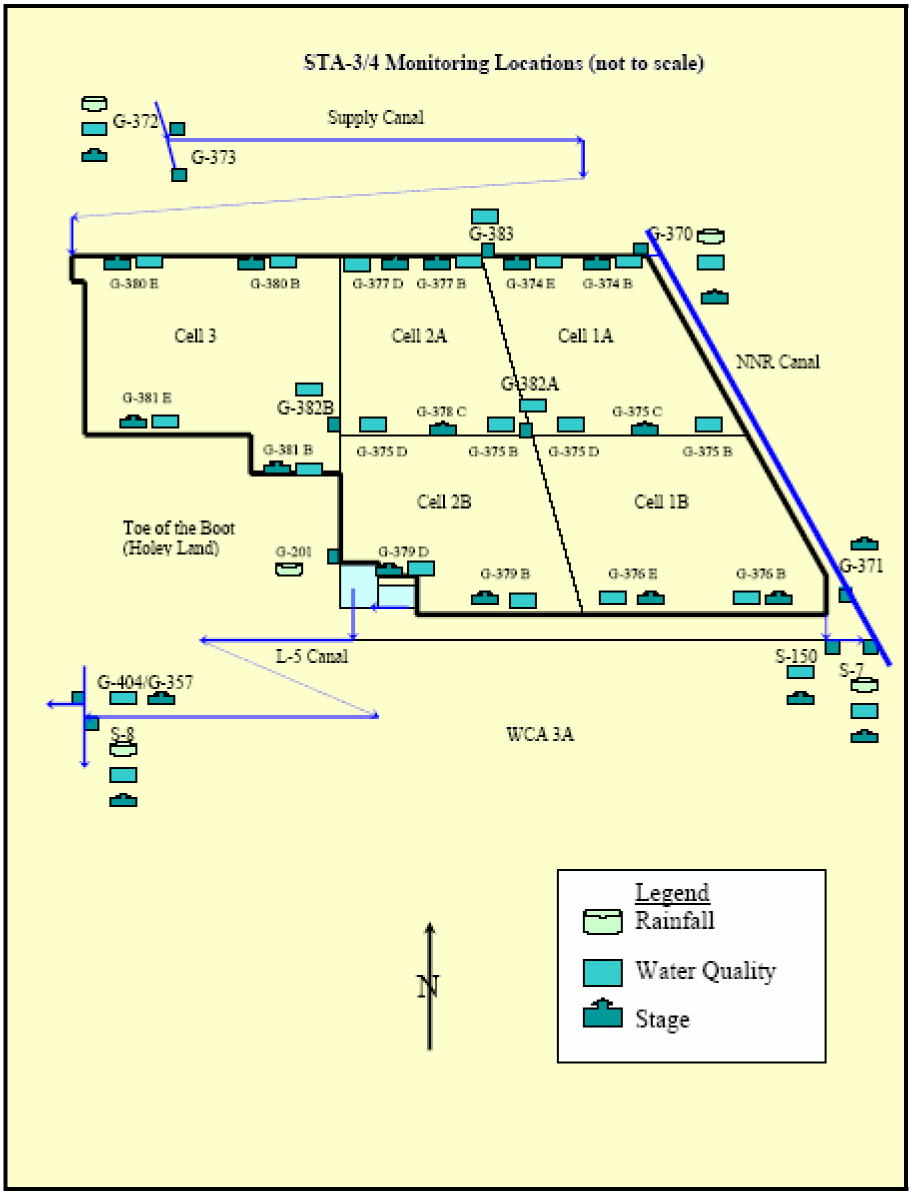

Figure 7 Location of Stage Monitoring Stations

4.3 Model Calibration and Validation Results

The mean error, mean absolute error and the root mean square error (RMSE) between computed and observed stage data were used to judge and improve calibration results by manually adjusting model parameters. The main adjusted parameter is the Manning' n value.

Current model calibration results obtained different Manning's n values for Cell 1 and Cell 2 vegetation to better match historical stages in each cell. As a reference, STA-3/4 design modeling study applied a single Manning's n depth-dependent relationship: cattail

(0.5, 1.3) for all cells (Burns & McDonnell, 2000). This was used as the base value for model calibration. The final Manning's n values (Table 1) for the current modeling effort were obtained after adjustment for better history matching in both model calibration and validation.

Table 1: Calibrated Manning's n Values used for STA-3/4

Depth (ft)	Cattail with open water (Cell 1A and 1B)	Cattail (Cell 2A)	SAV (Cell 2B)	Canals
3.0	0.5	0.8	0.3	0.036
1.5	Varies linearly	Varies linearly	Varies linearly	
1.0	1.0	1.3	Varies linearly	
0.5	1.0	1.3	0.8	

Most differences between computed and observed stages are within ±0.25 ft. The RMSE is below 0.15 ft. The mean error, mean absolute error and RMSE values for all stage stations in Cells 1A and 1B are 0.04 ft, 0.06 FT and 0.08 ft and Cell 2 has similar error magnitude.

The major uncertainties in model calibration include: (1) the culvert option is a simplified representation of the STA-3/4 gated culverts. The culvert parameters are not calibrated and complex culvert flow conditions are lumped into two flow cases. The computed culvert flow rates provide flow to the downstream cells and this likely will affect computed water levels. (2) A simple piecewise linear depth-dependent relationship is used to represent the effect of vegetation on flow resistance. (3) Seepage losses from STA-3/4 are not well quantified and are neglected in the model. (4) Flow and stage observations are located near flow structures. No interior stage monitoring stations are provided in the marsh areas.

The following time series plots provide visual comparison of computed and observed stages during the selected time periods.

Eastern Flow-way: Cell 1

There are 10 measured stage stations in Cell 1. They are G374B_H/G374B_T, G374E_H/ G374E_T, G375C_H/G375C_T and G376B_H/G376B_T, and G376E_H /G376E_T. G374B_H and G376B_T were used as specified stage boundary conditions. The water levels in Cell 1 during model calibration and validation periods are plotted together in Figure 8.

During model calibration, computed stages in Cell 1A (G374 TW and G375 HW) were overestimated but matched with observed values quite well in model validation. In Cell 1B, simulated water levels (G375 TW and G376 HW) were within ± 0.25 ft of the observed values, overestimate at G376 HW during model validation phase occurred with an underestimate to good match at G375 TW.

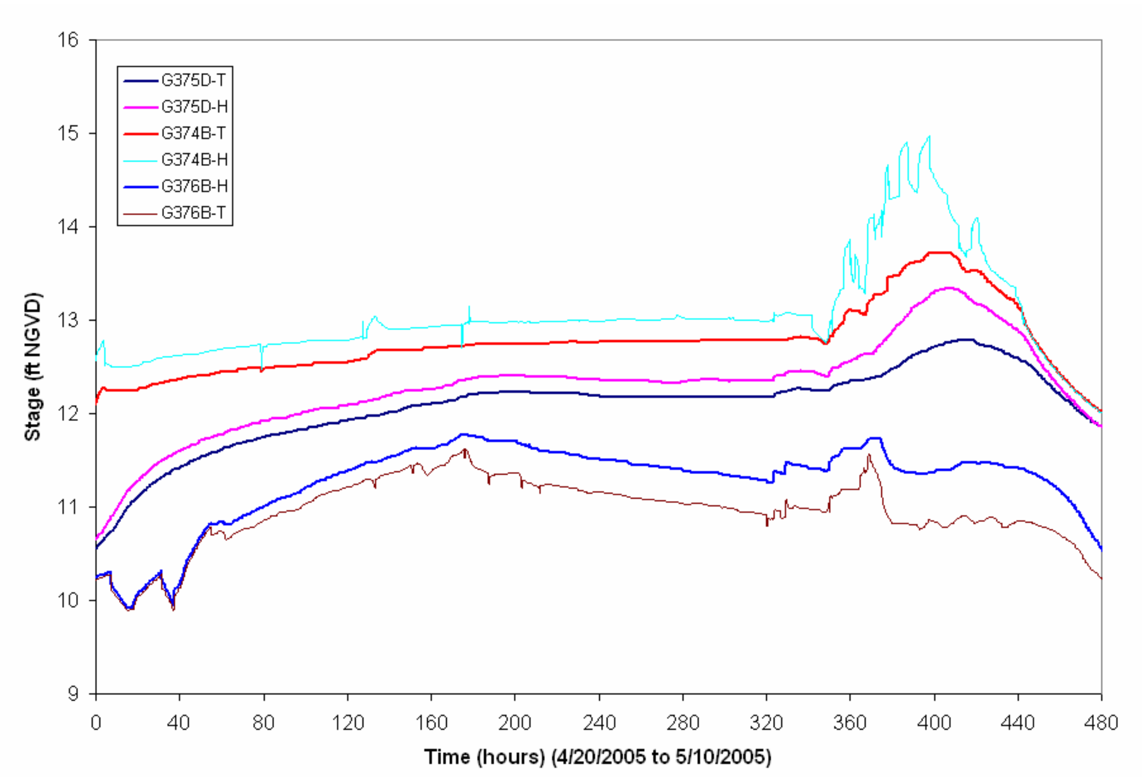

Figure 8: Observed Stage Hydrograph for Cell 1 (Model calibration and validation)

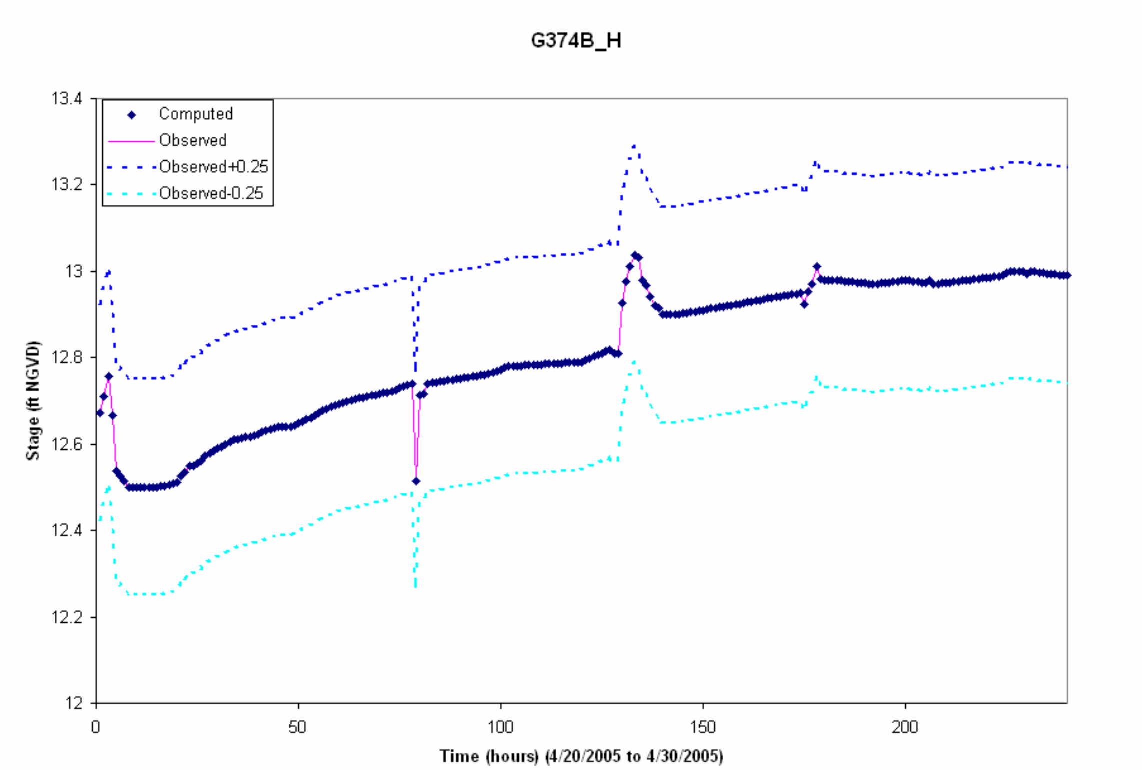

Figure 9 Model Calibration Result: G374B_H (as boundary condition)

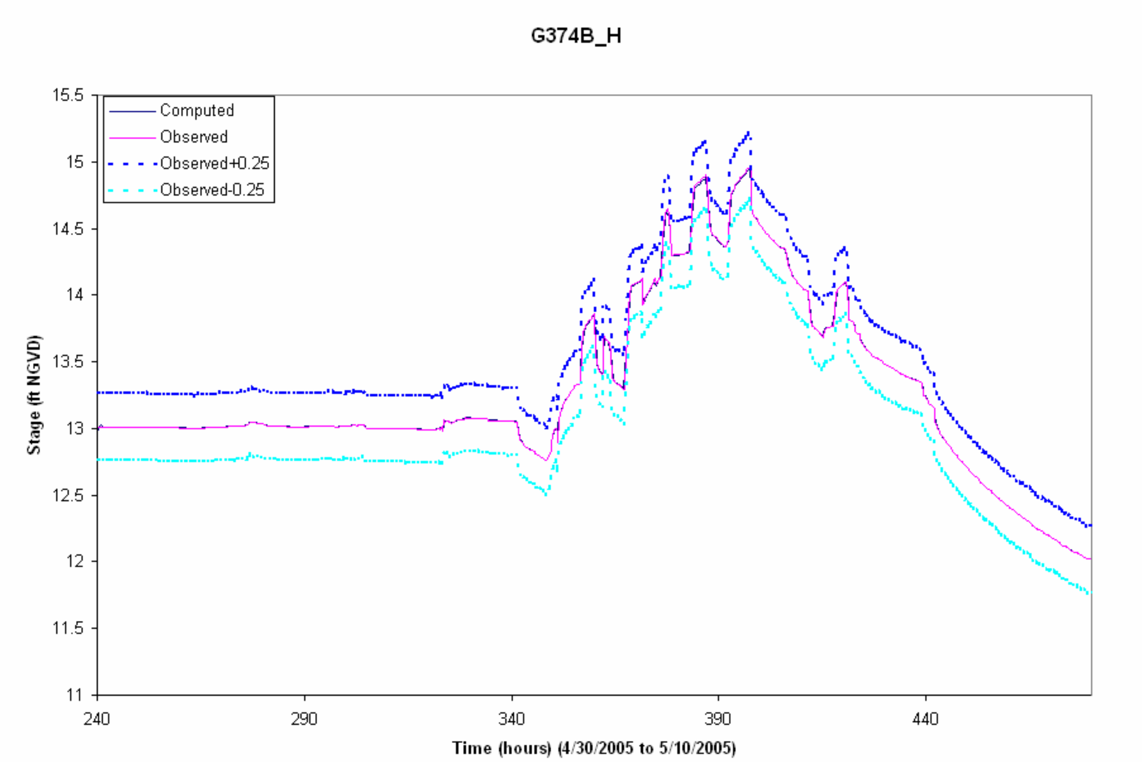

Figure 10 Model Validation Result: G374B_H (as boundary condition)

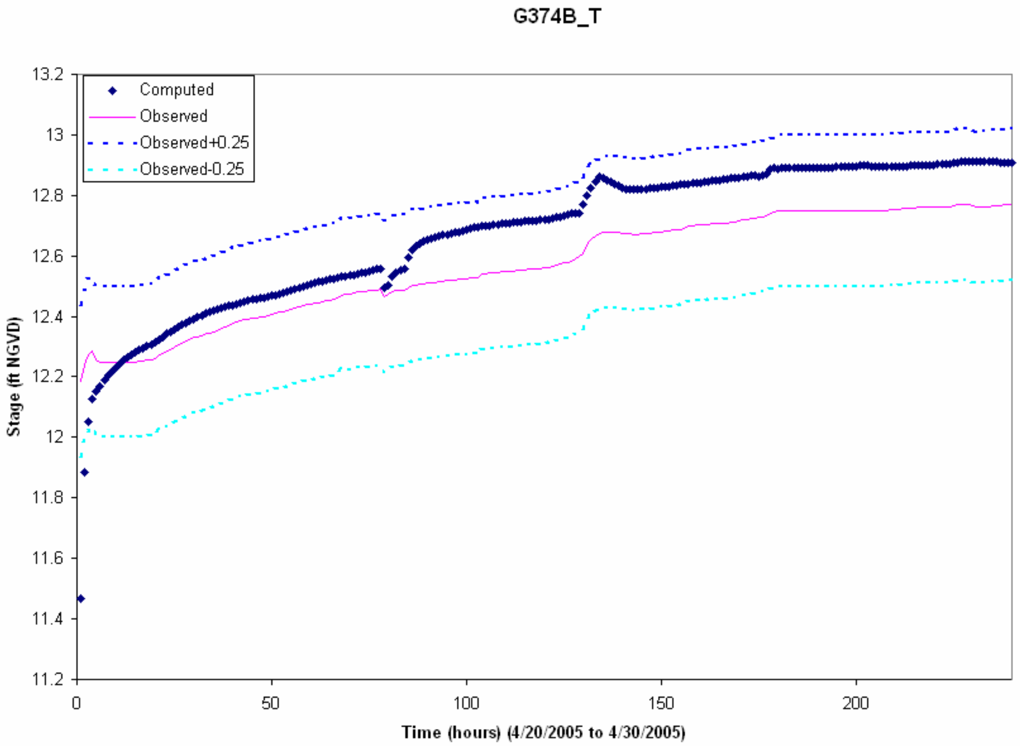

Figure 11 Model Calibration: G374B_T

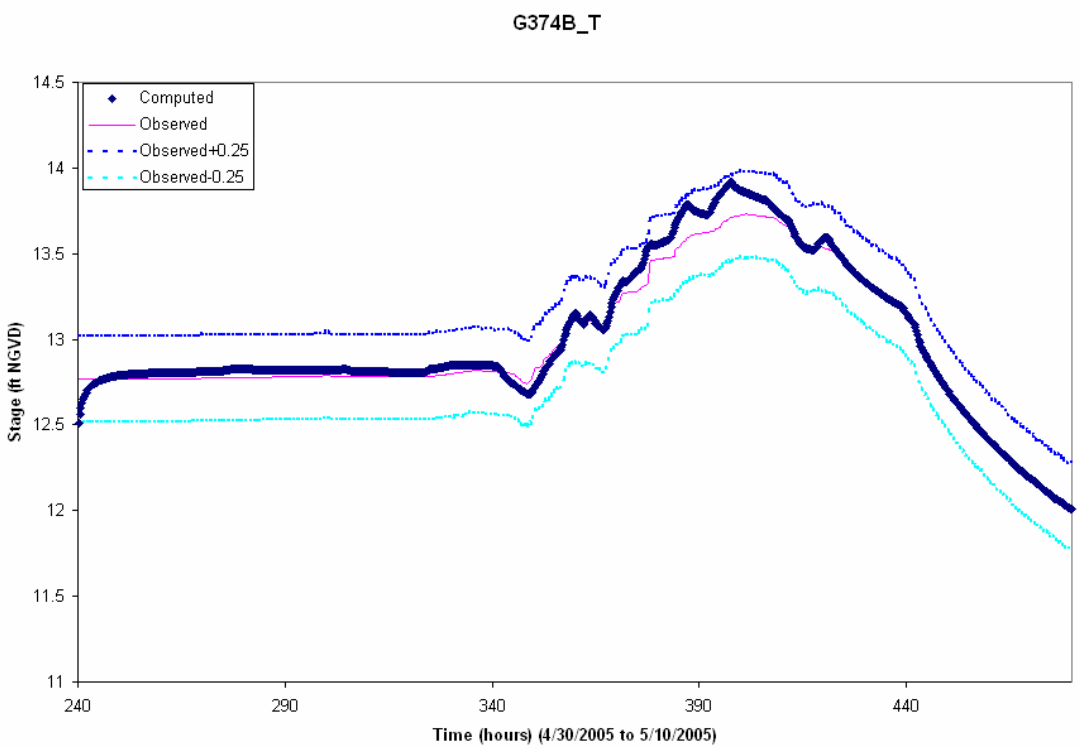

Figure 12 Model Validation: G374B_T

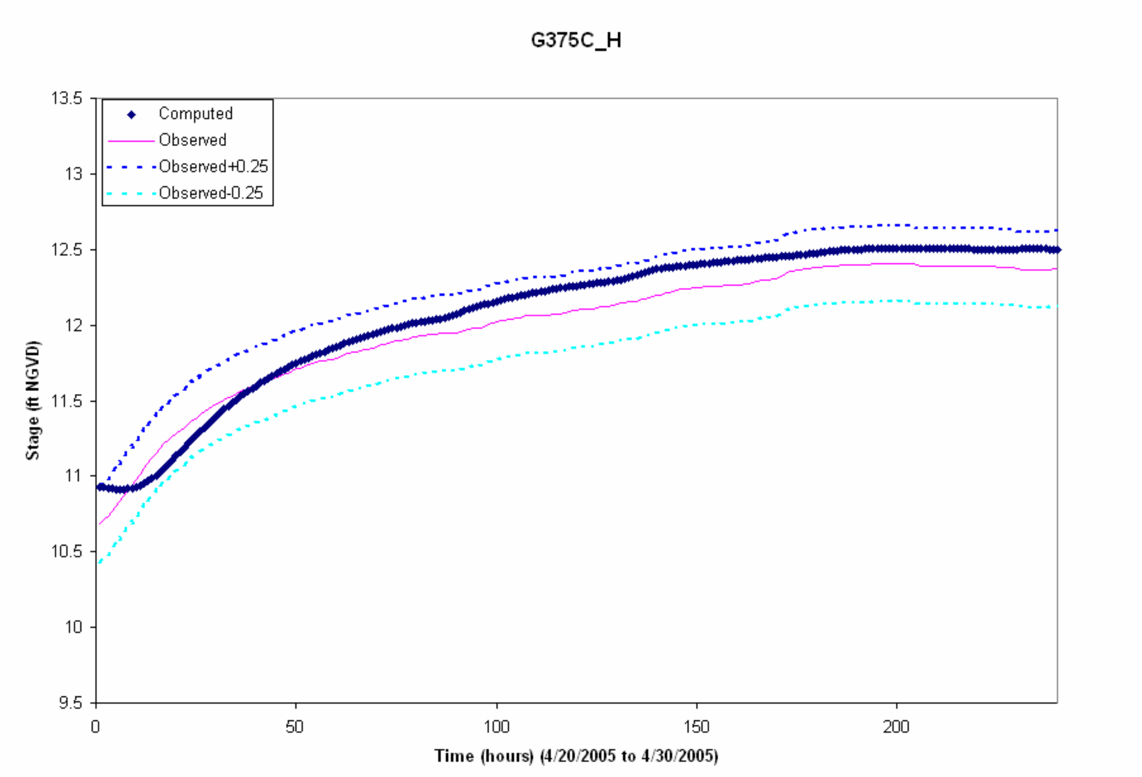

Figure 13: Model Calibration: G375C_H

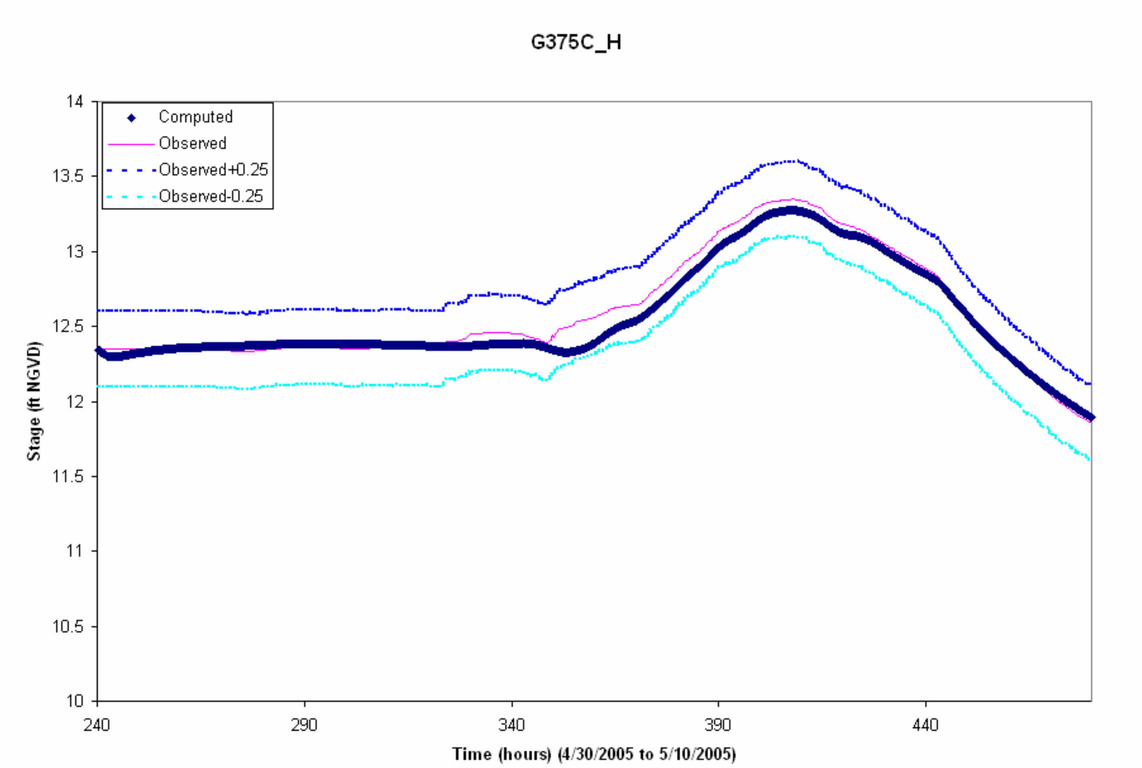

Figure 14 : Model Validation: G375C_H

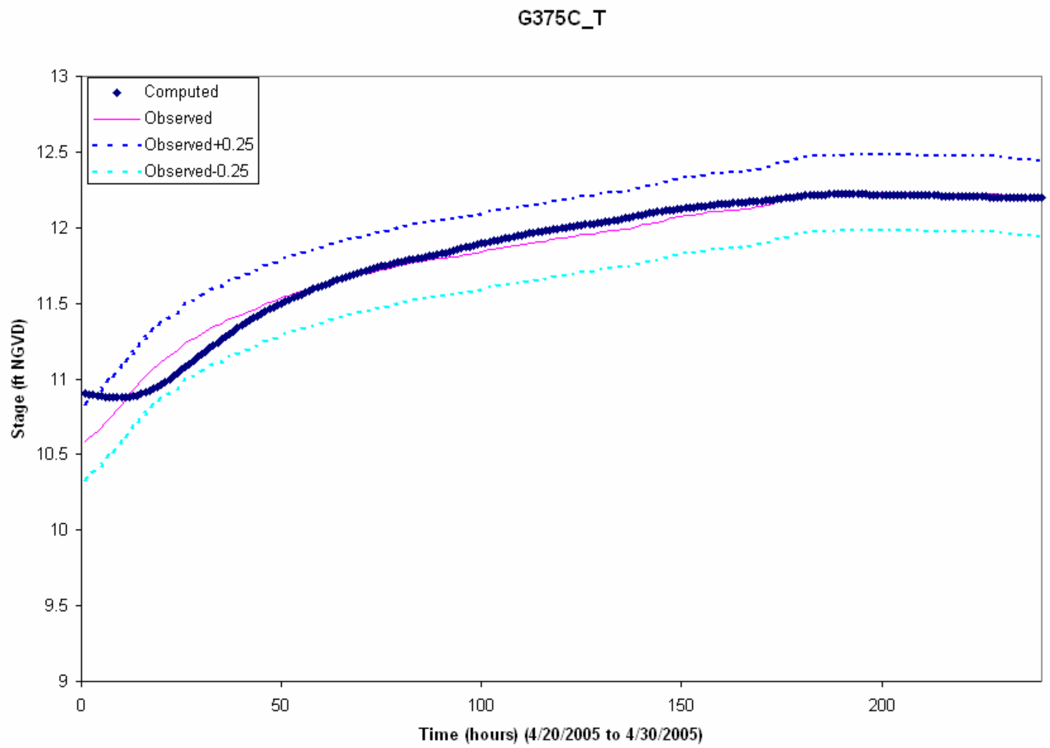

Figure 15: Model Calibration: G375C_T

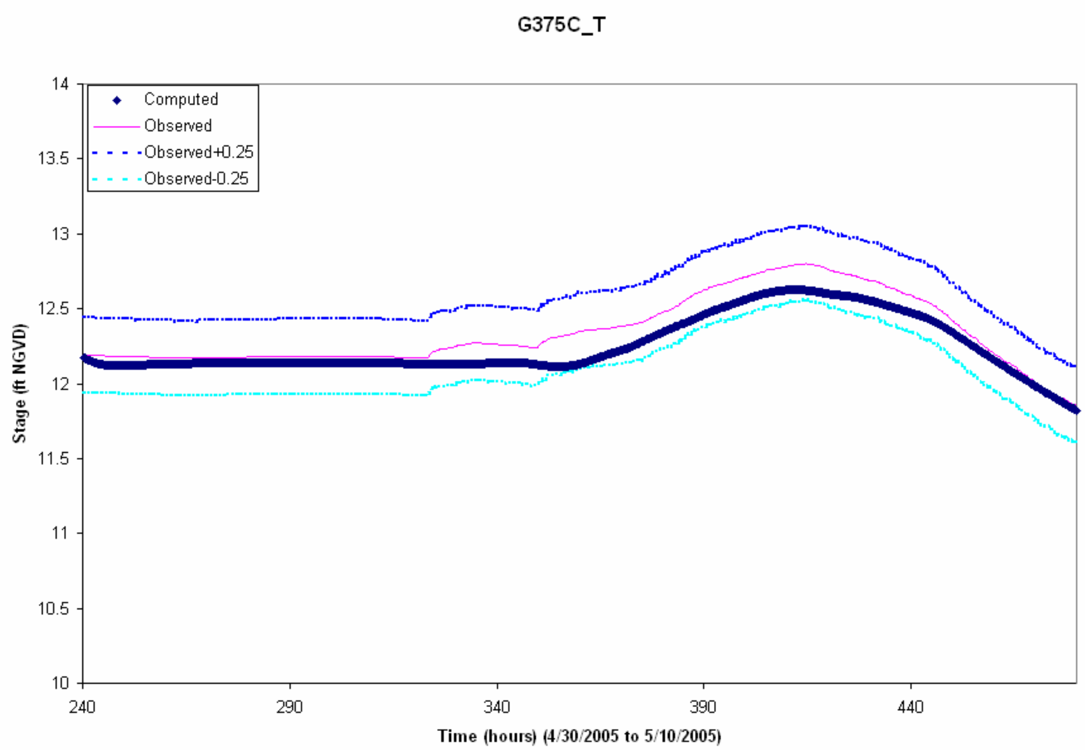

Figure 16: Model Validation: G375C_T

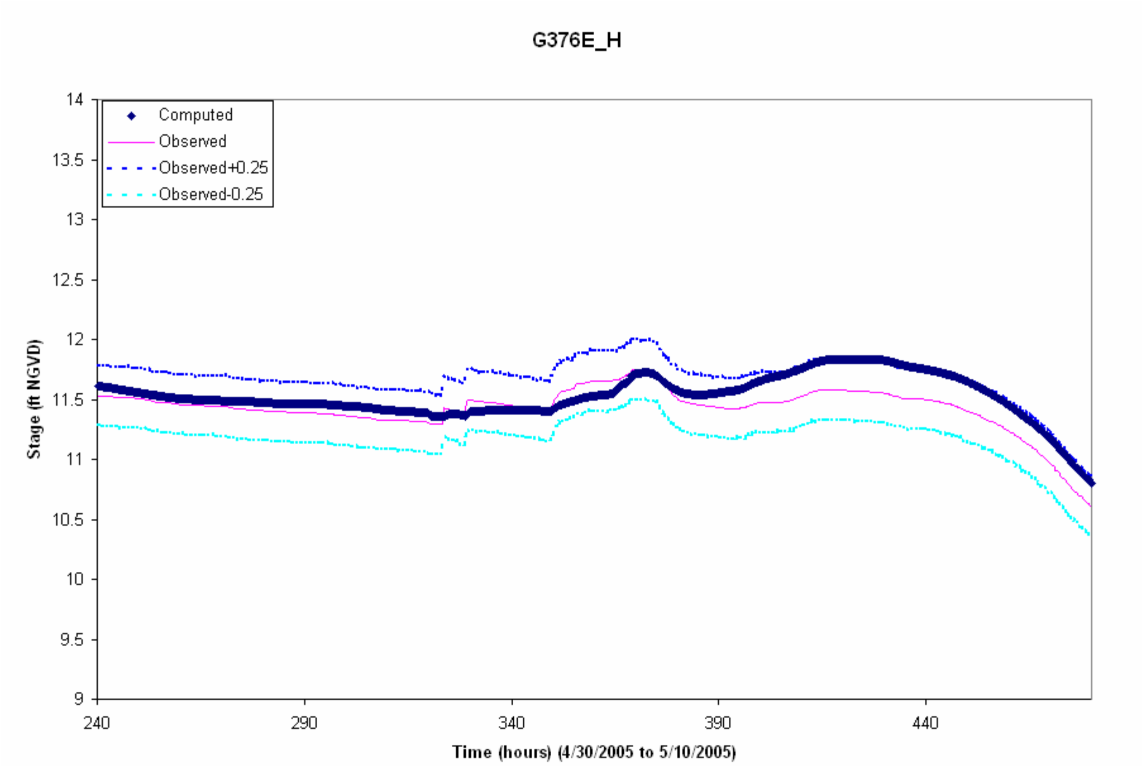

Figure 17 Model Validation: G376E_H

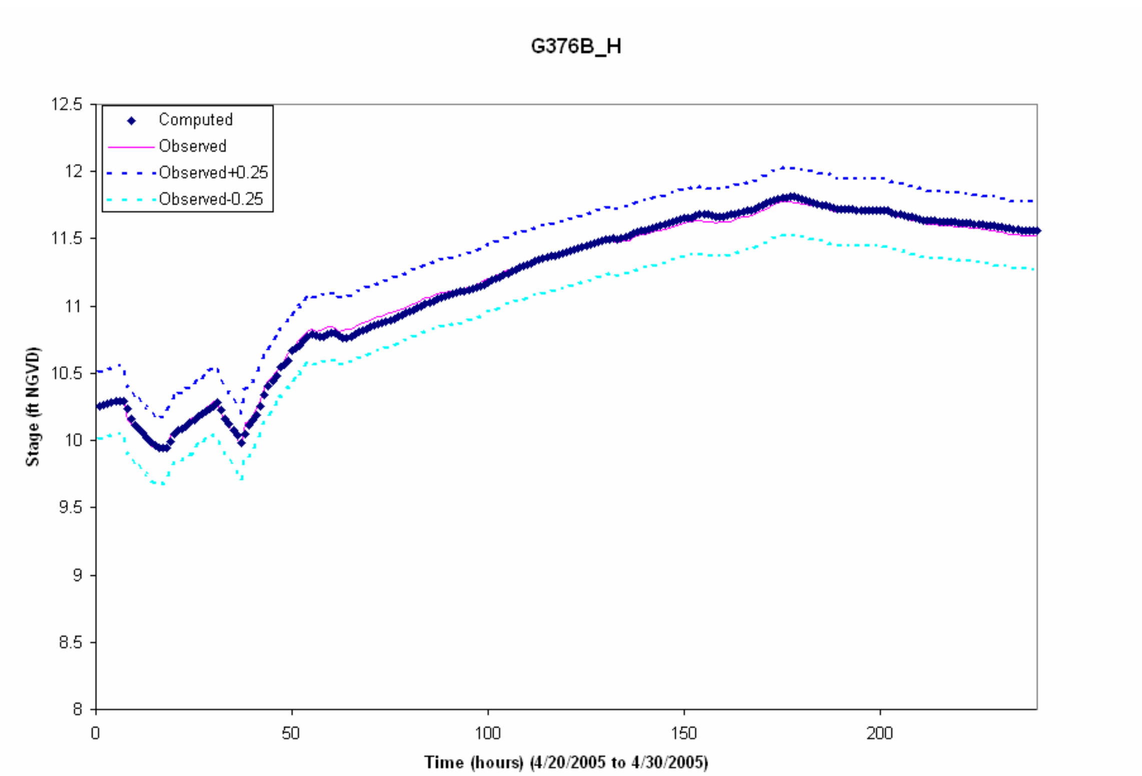

Figure 18 Model Calibration: G376B_H

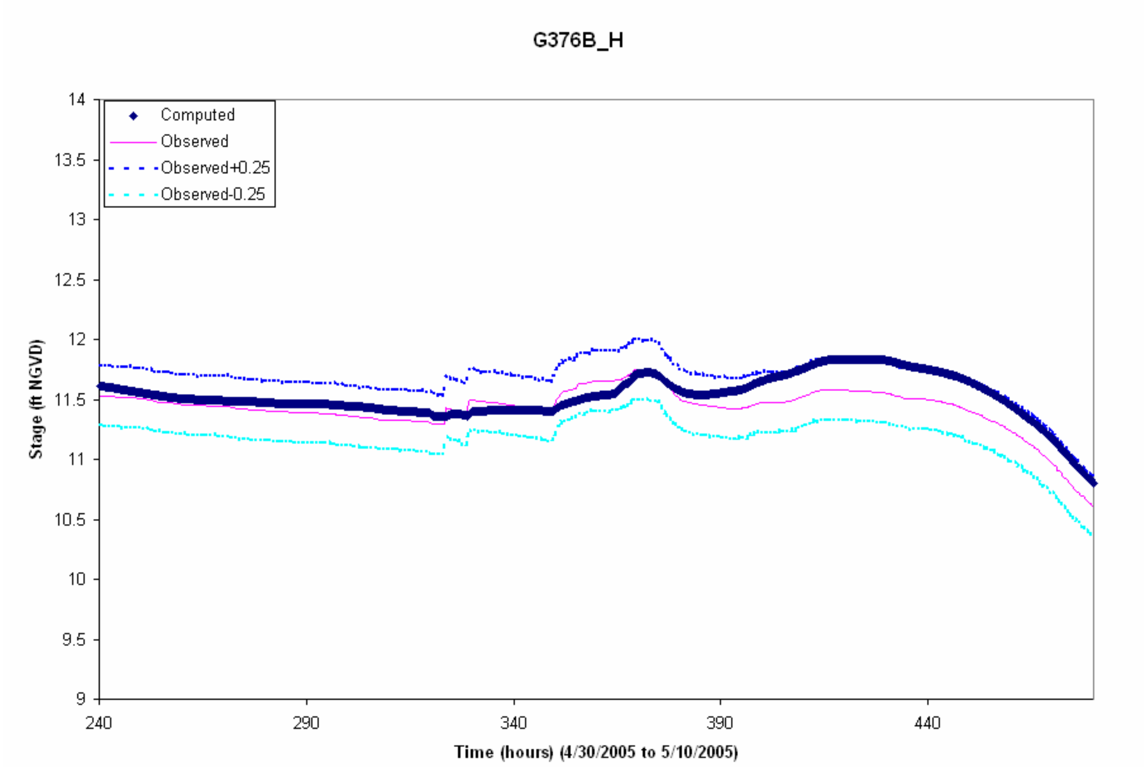

Figure 19 Model Validation: G376B_H

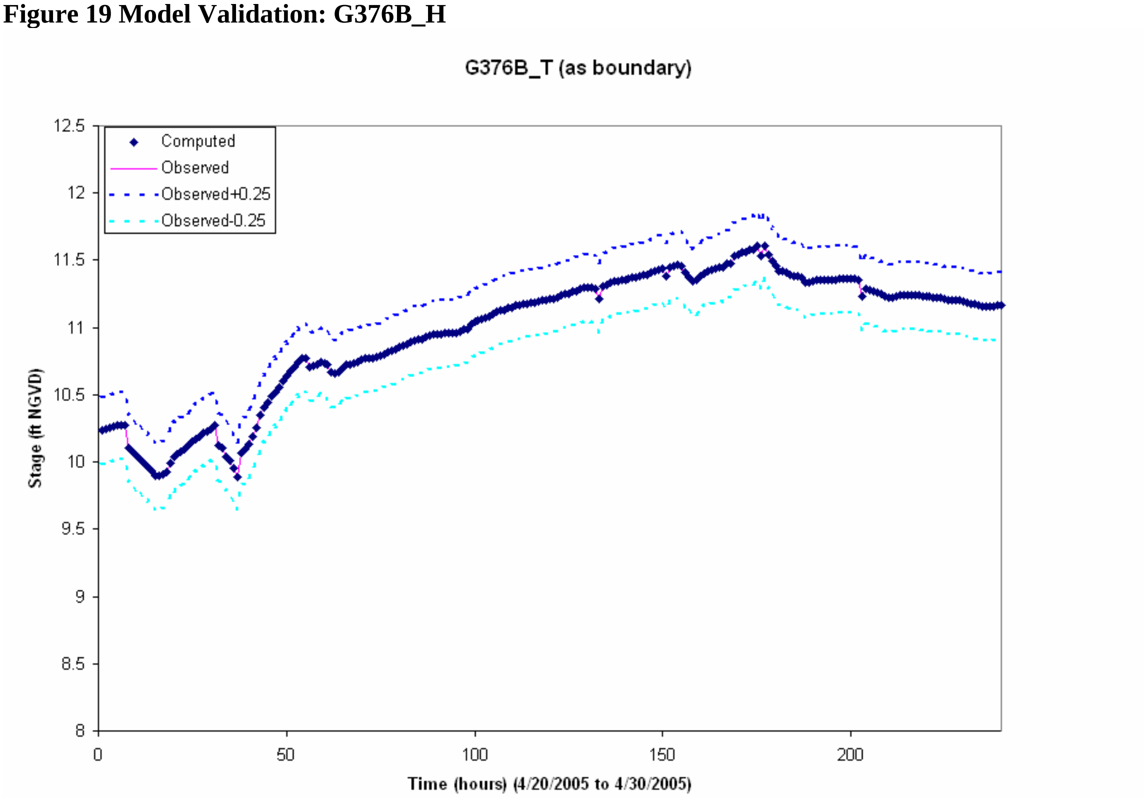

Figure 20 Model Calibration: G376B_T (as boundary condition)

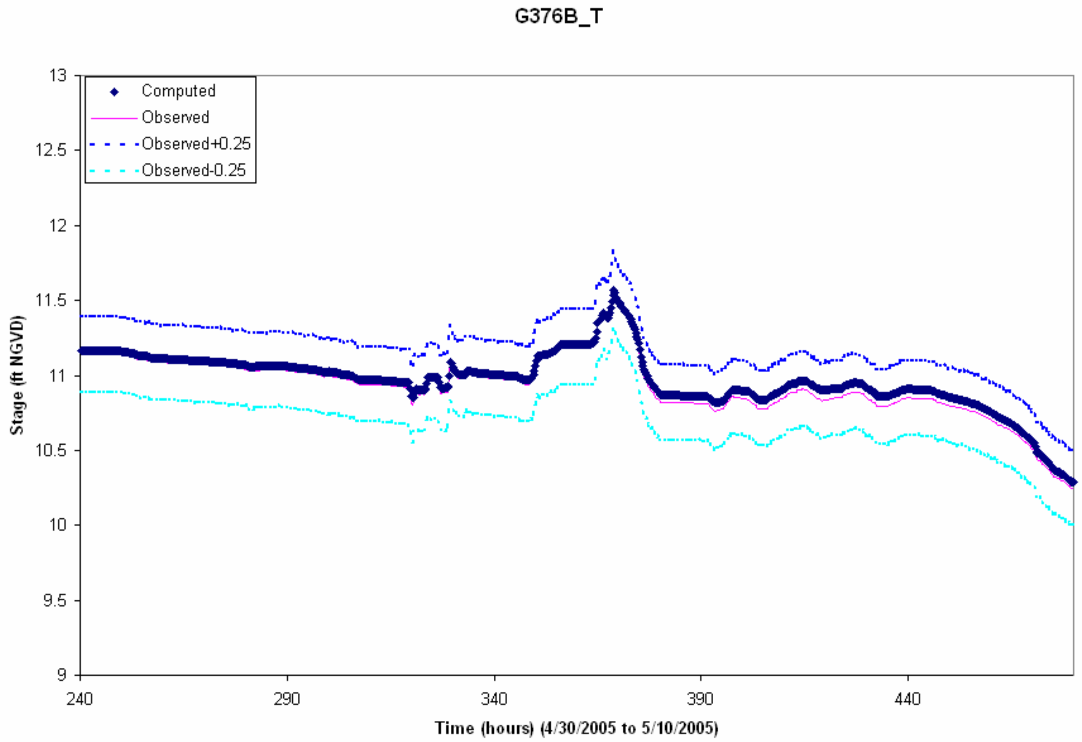

Figure 21 Model Validation: G376B_T (as boundary condition)

Central Flow-way: Cell 2

There are 10 measured stage stations in Cell 2. They are G377B_H/G377B_T, G377D_H /G377D_T, G378C_H/G378C_T and G379B_H/G379B_T, and G379D_H/G379D_T. G377D_H and G379B_T were used as specified stage boundary conditions. The observed stages in Cell 2 during model calibration and validation periods were plotted together in Figure 22.

During the 36 hours from the beginning of model calibration, G379D was closed but this could not be simulated in the model (Figure 31), the deviation in G379D Headwater level (HW) was significant. FLO2DH does not have the option of partial gate openings for culverts. A good match was obtained for the same location after this time period. The errors in history matching for G378C_H and G378C_T are within ± 0.25 ft. However, as can be seen from the plots, the final calibration results are largely produced by adjustments to meet this target, for example, computed G378C_H stage values were underestimated during model validation phase, at the same time, there is a good match for G378C_T.

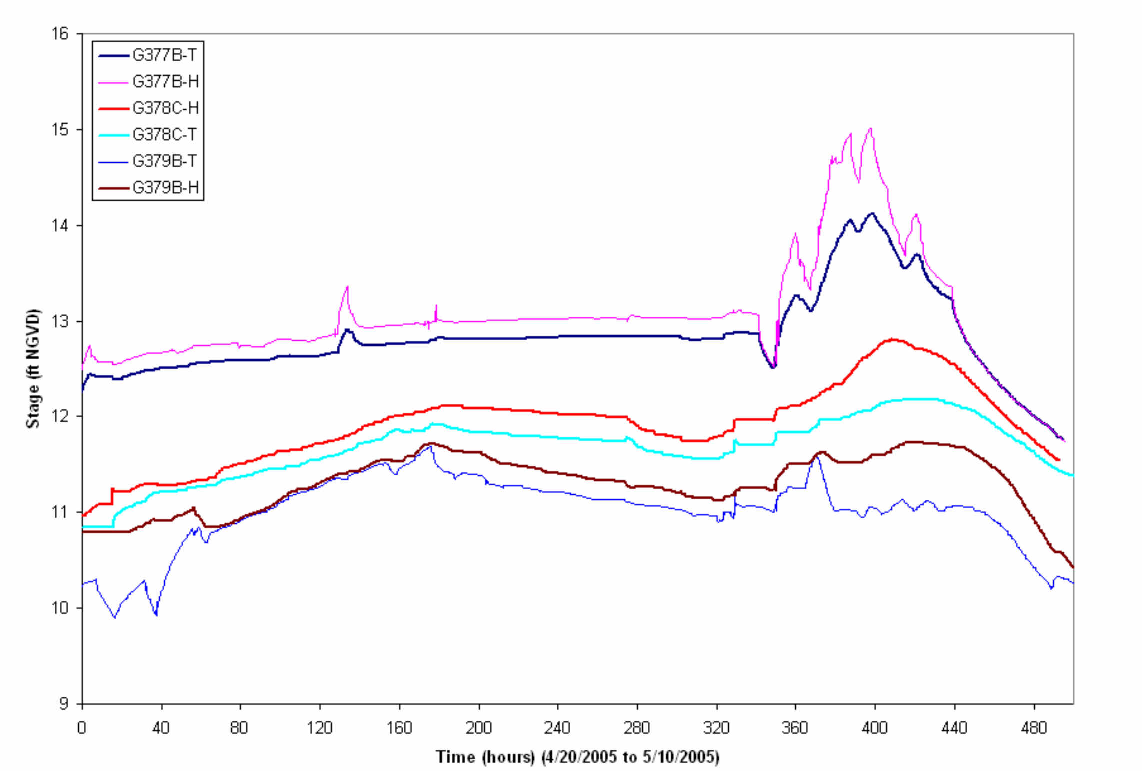

Figure 22: Observed Stage Hydrograph for Cell 2 (Model calibration and validation)

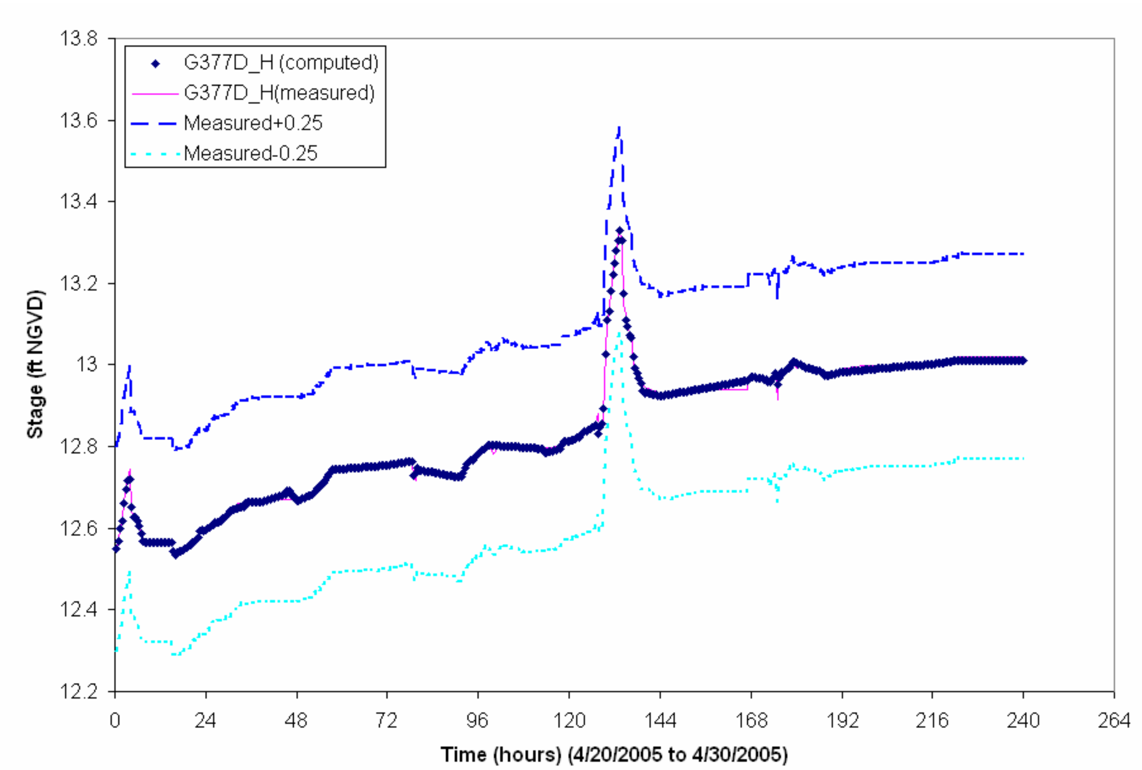

Figure 23 Model Validation: G377D_H (as boundary condition)

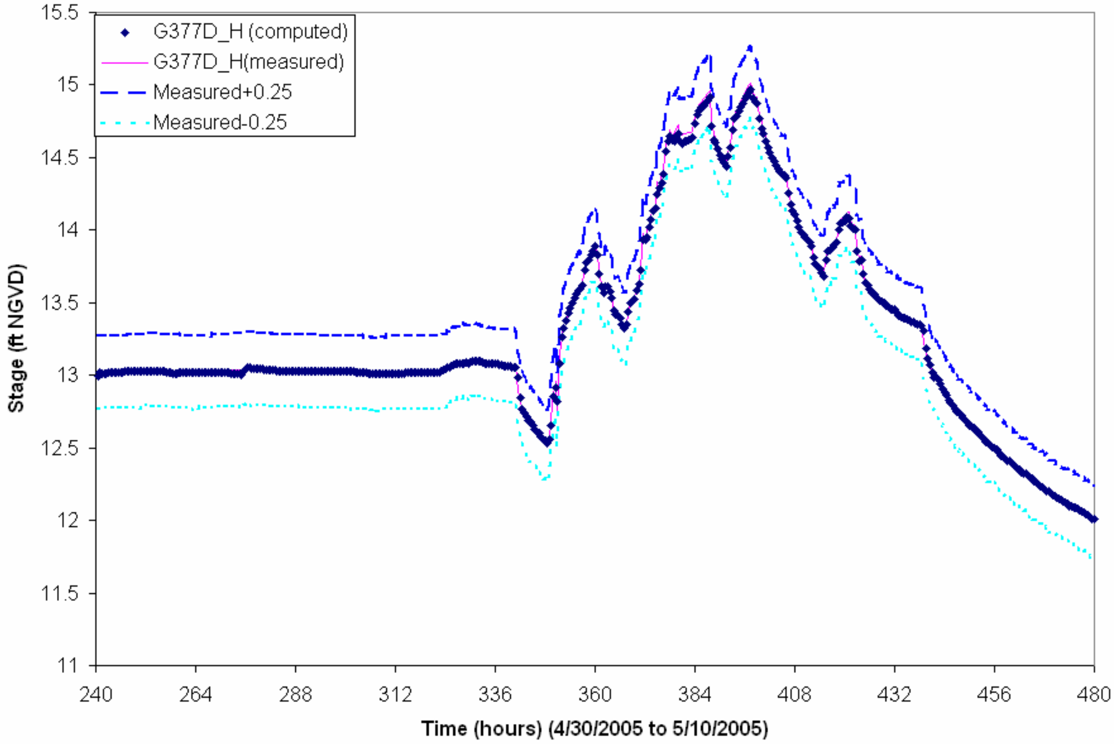

Figure 24 Model Validation: G377D_H (as boundary condition)

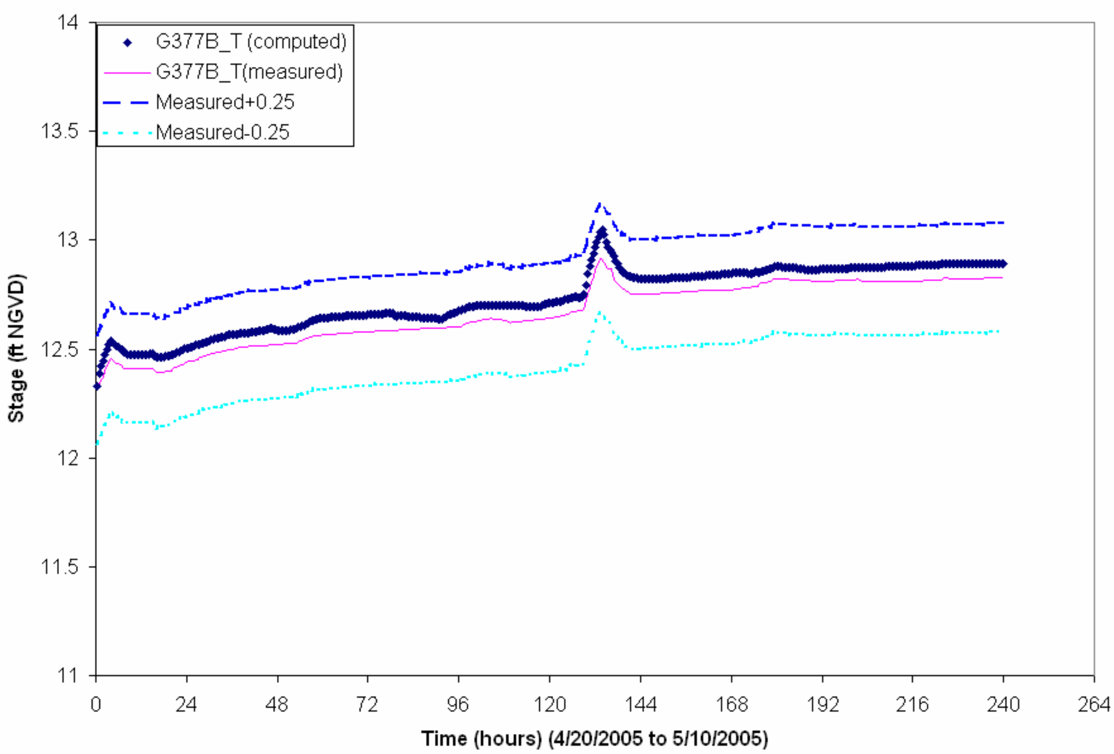

Figure 25 Model Calibration: G-377B_T

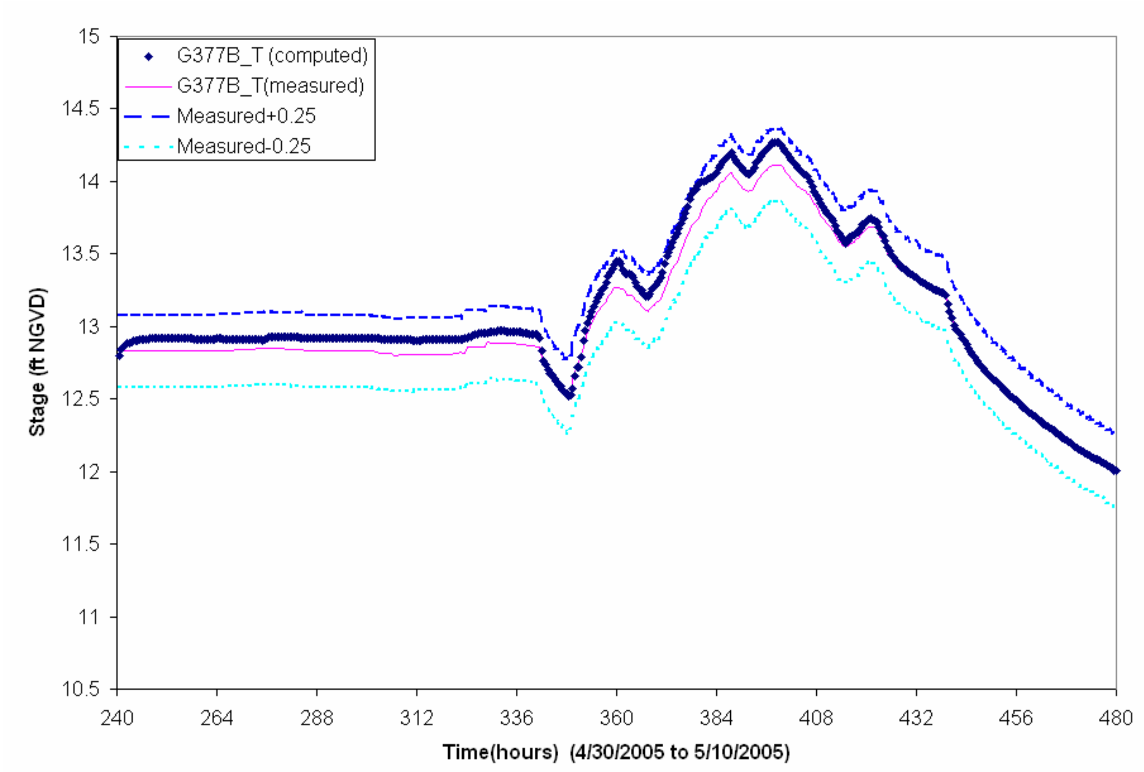

Figure 26 Model validation: G-377B_T

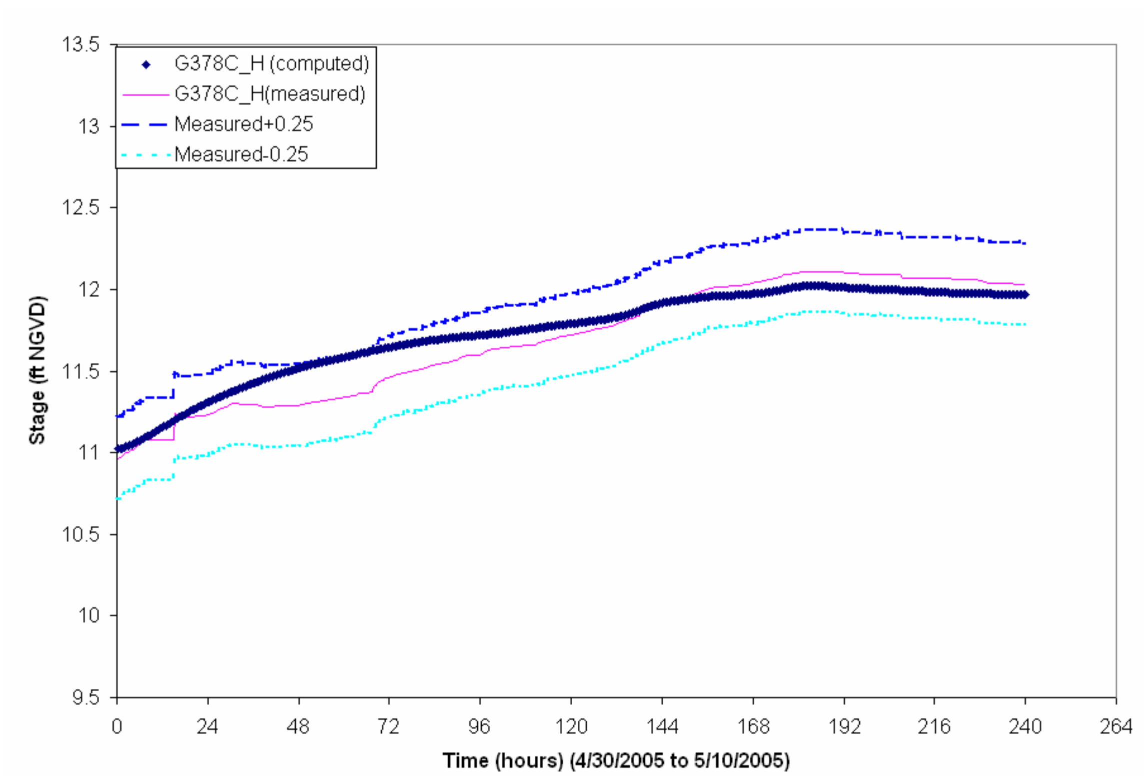

Figure 27 Model Calibration: G-378C_H

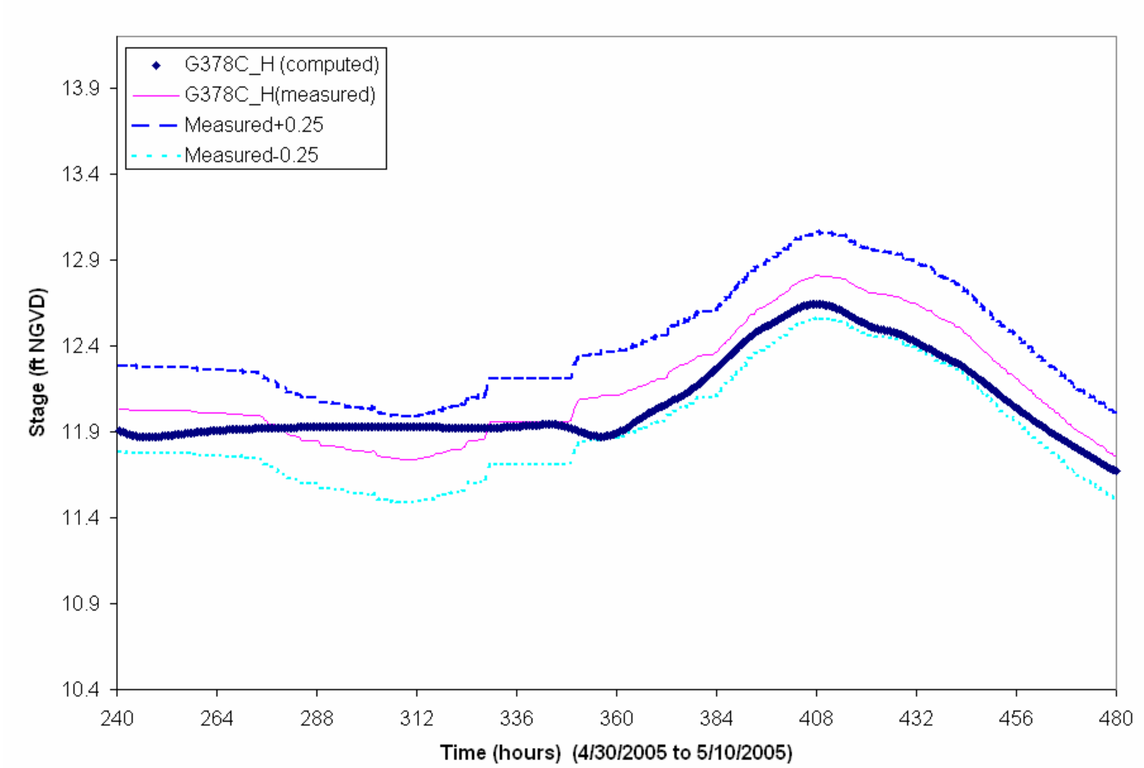

Figure 28 Model Validation: G-378C_H

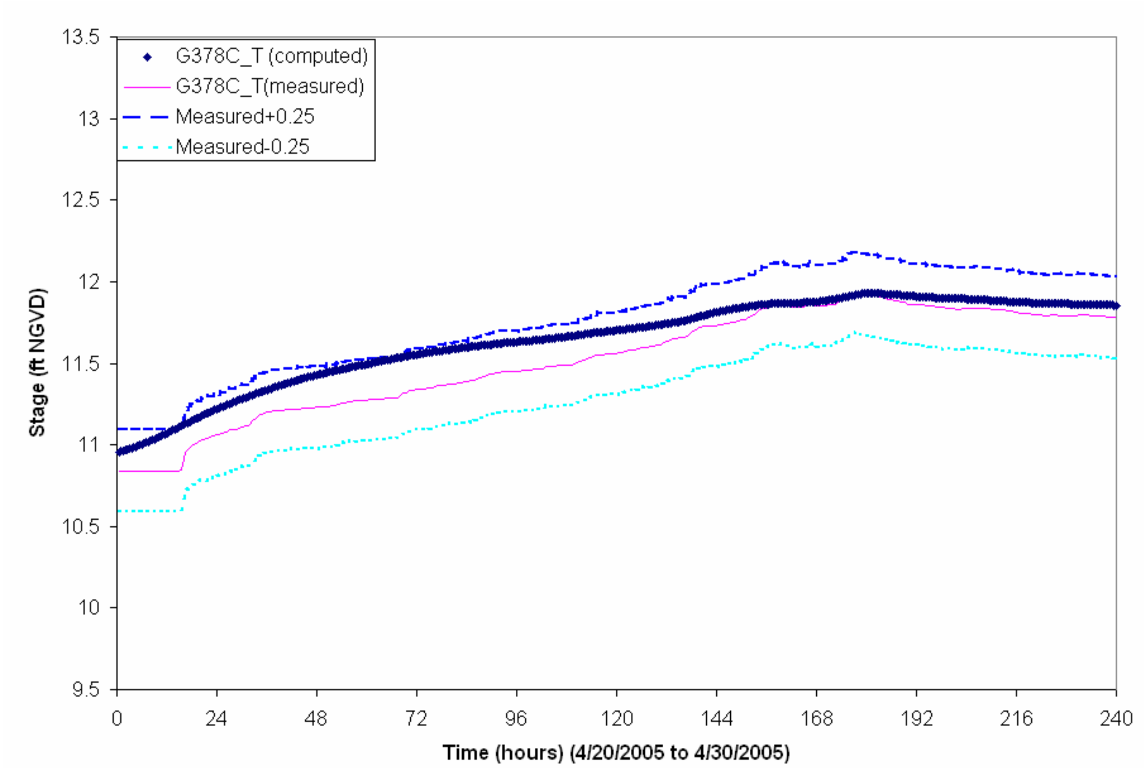

Figure 29: Model Calibration: G-378C_T

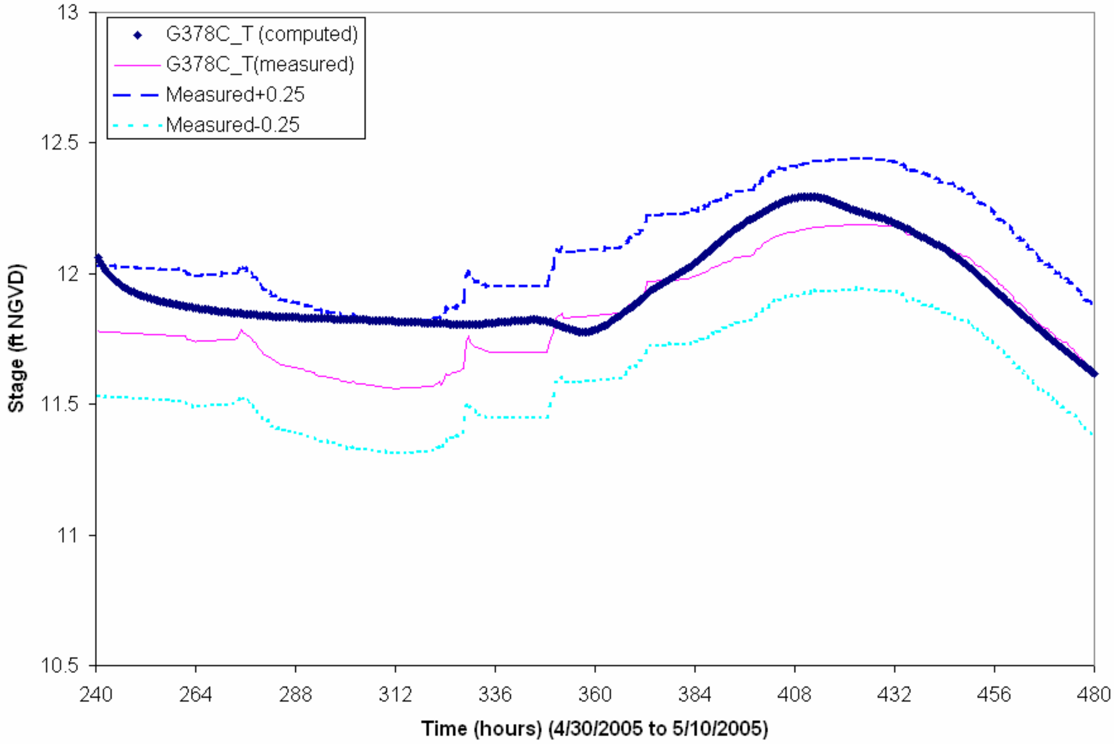

Figure 30: Model Validation: G-378C_T

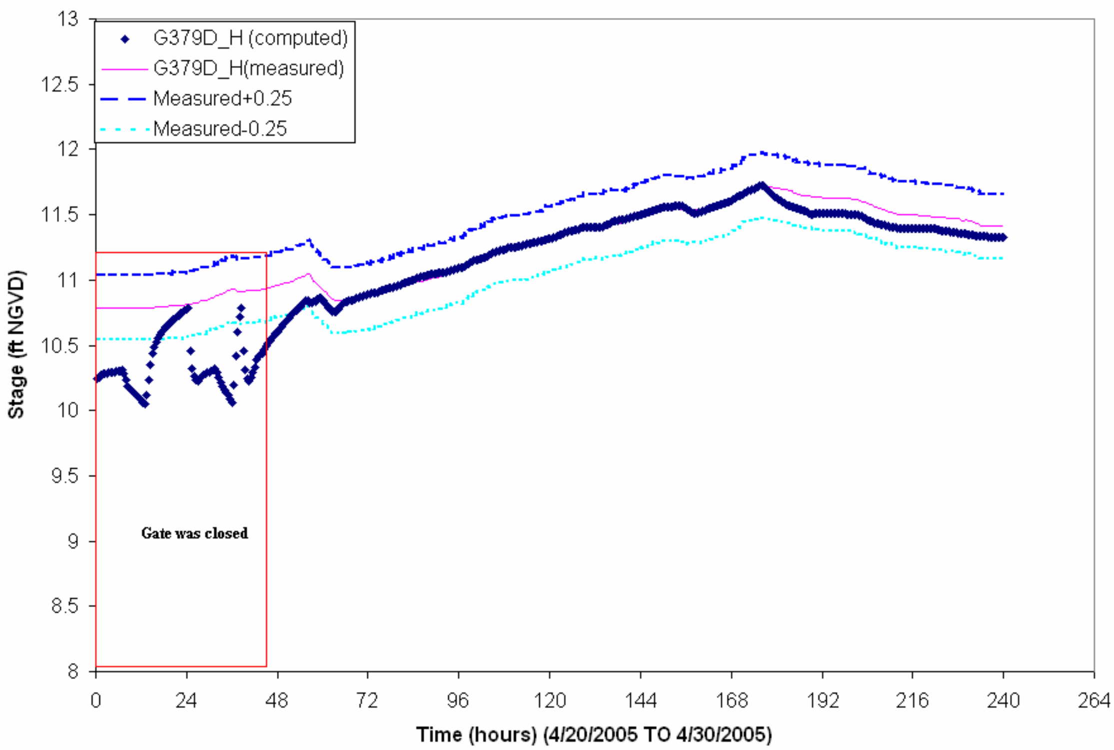

Figure 31: Model Calibration: G-379D_H (Gate was closed during the first 36 hours, not simulated in the model)

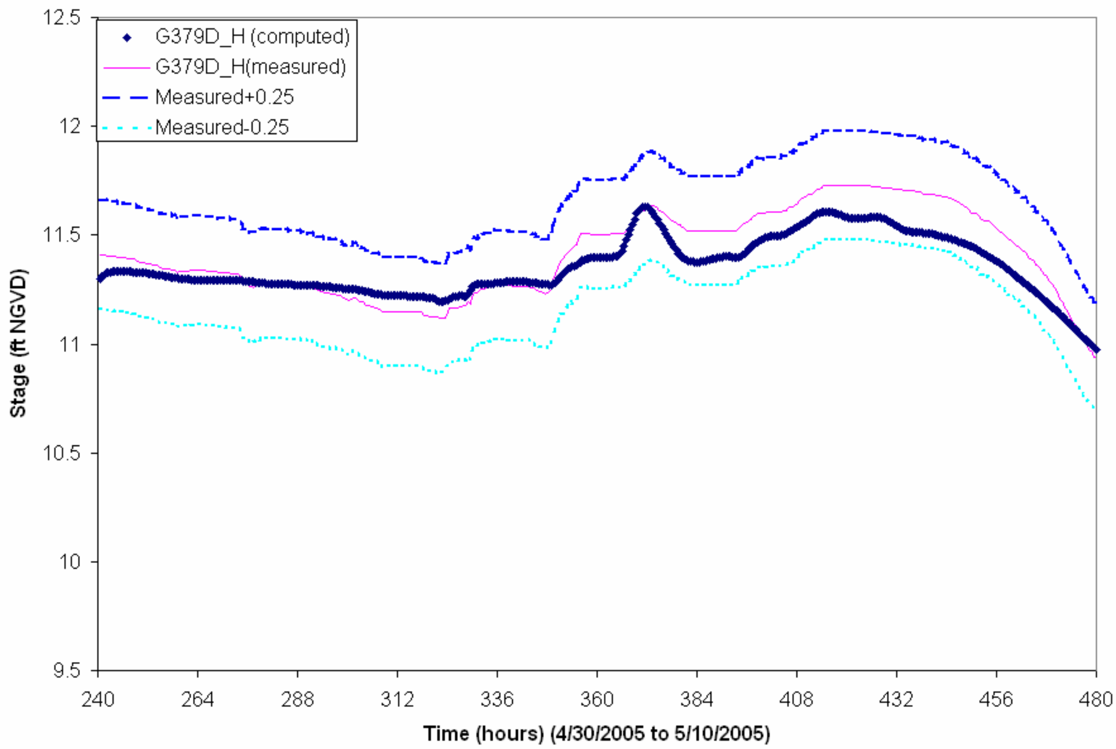

Figure 32: Model Validation: G-379D_H

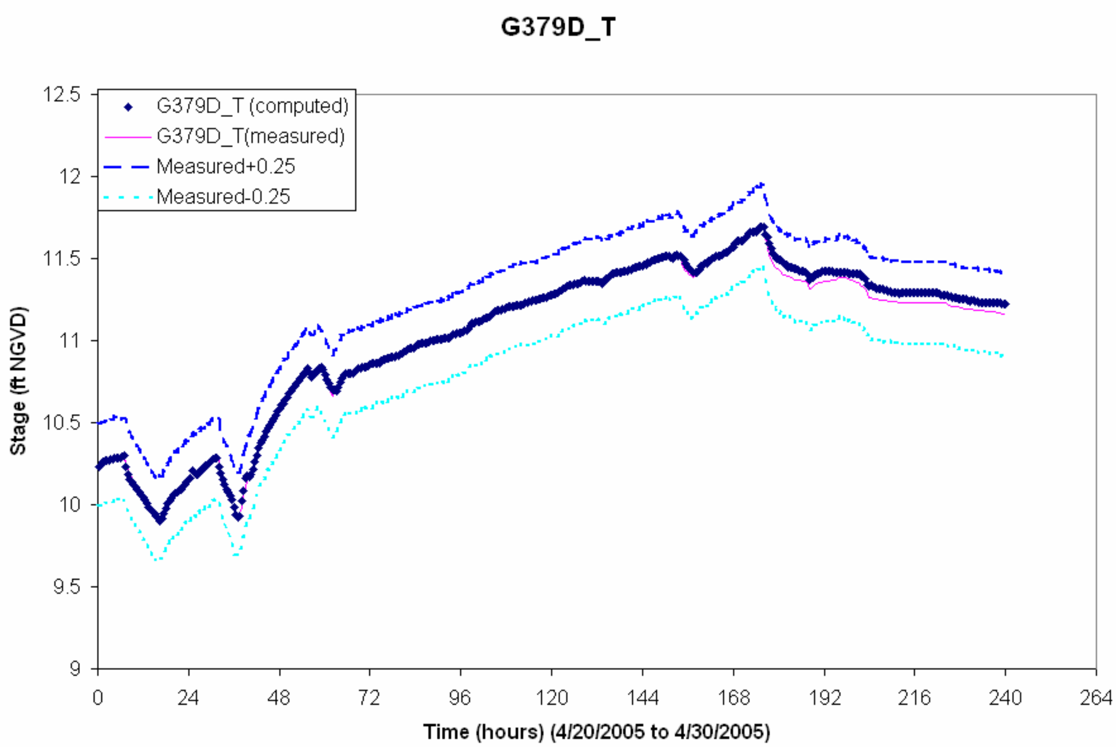

Figure 33 Model Calibration: G-379D_T

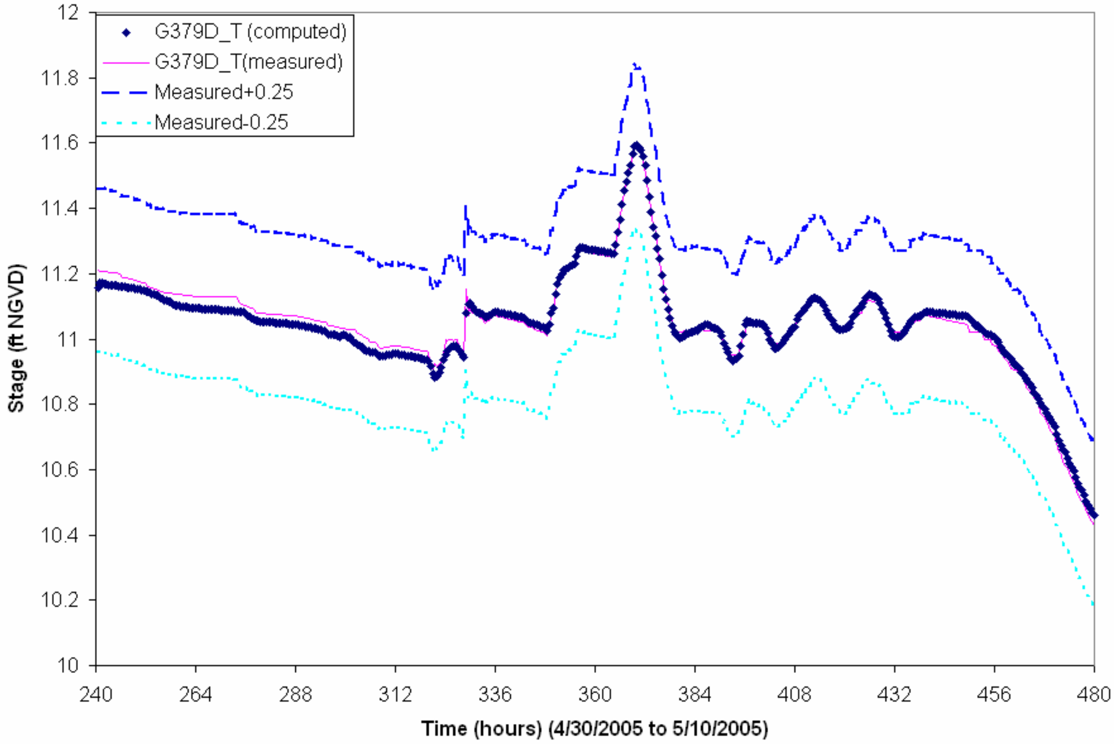

Figure 34 Model Validation: G-379D_T

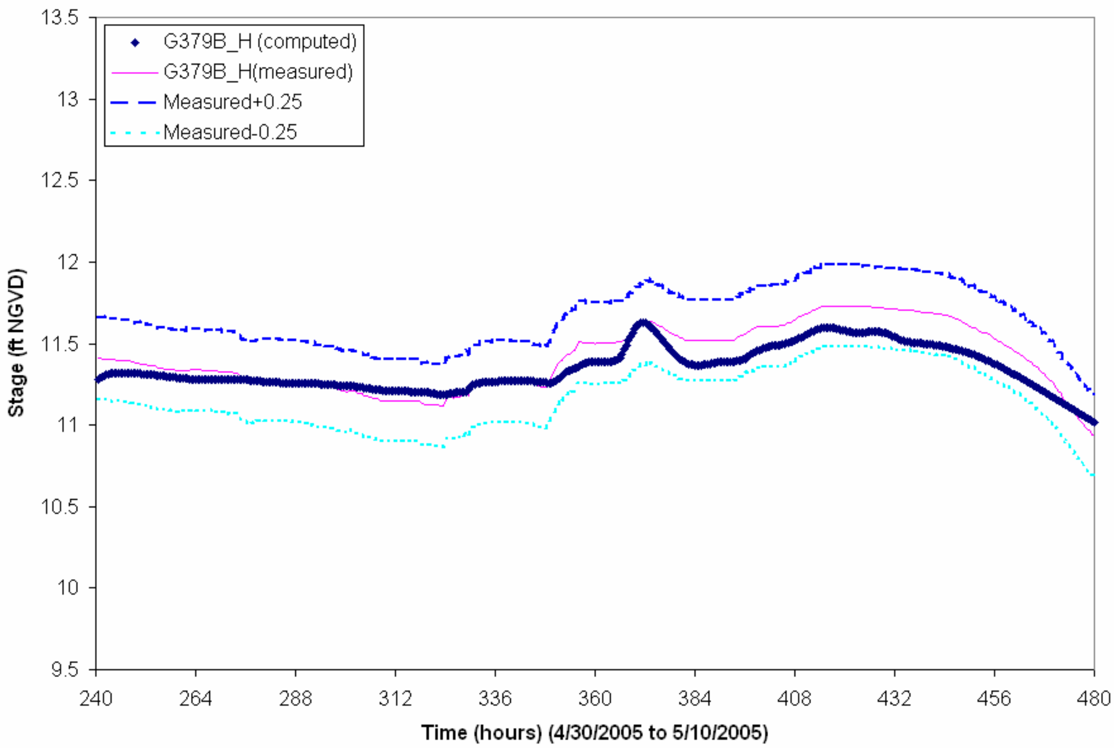

Figure 35 Model Validation: G379B_H

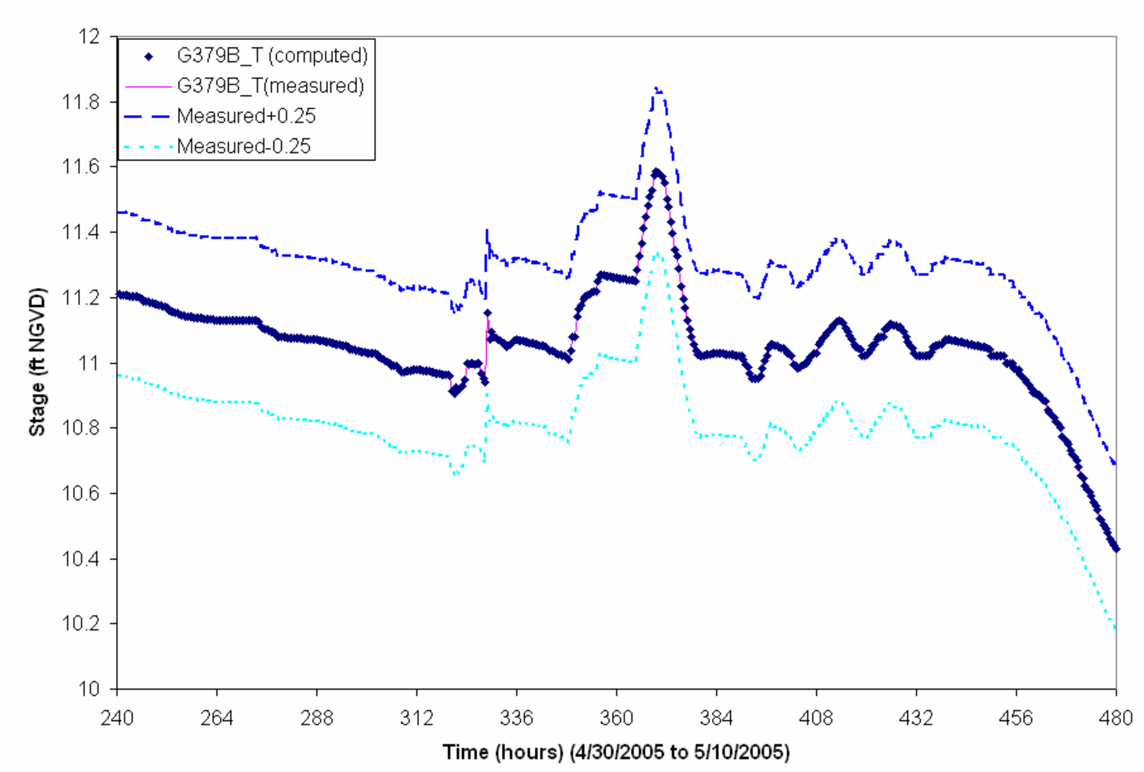

Figure 36 Model Validation: G-379B_T (as boundary condition)

5. Steady Flow Simulations

Since STA-3/4 is relatively new and enhancements are currently underway, the enhanced configuration as described in the revised Long-Term Plan for Achieving Water Quality Goals (SFWMD, 2004a) was simulated for Design Peak Flow, Low and High Flows.

The main assumption is that Cells 1B, 2B and 3B are SAV dominant; Cell 3 is currently being divided into 3A and 3B by an interior levee. The overall linked cells model comprises the Inflow/Supply Canal, Cells 1A/1B, 2A/2B and 3A/3B, and the Discharge Canal. All 51 culverts are explicitly represented.

From previous STA design criteria documents, the following hydraulic performance measures are preferred (Burns & McDonnell, 2000):

- Minimum water depth: 0.5 ft
- Maximum water depth: 90% of area less than 4.5 ft
- Maximum velocity in marsh areas: 0.1 ft/s.

The steady flow simulation results will be judged by how these criteria are satisfied.

5.1 Design Peak Flow

Under Design Peak Flow condition, STA-3/4 total inflow is 6,440 cfs. This includes 2,770 cfs from G-370 and 3,670 cfs from G-372.

Desired downstream stage levels in the Discharge Canals are applied as specified stage boundary conditions obtained from the STA-3/4 Operation Plan. Stage at the western end of the Cell 3 Discharge Canal is 13.1 ft NGVD and stage levels downstream of G-379A-E and G-376A-F are 12.6 and 12.3 ft NGVD, respectively.

Since there are 51 culverts explicitly presented in the model, direct steady flow simulations were not convergent, i.e., they were not numerically stable. With constant boundary conditions, transient simulations were conducted to approach a final steady flow state. Mass balance error, water levels and velocity magnitudes were checked for the final results.

An accurate mass balance was obtained at the end of the Design Flow simulations (Table 2).

Table 2: Water Budget Obtained from FLO2DH Culvert Report (cfs)

Cell 1A Inflow		Cell 2A Inflow		Cell 3A Inflow	
Culvert	Computed Flow	Culvert	Computed Flow	Culvert	Computed Flow
G-374A	470.27	G-377A	490.719	G-380A	250.531
G-374B	466.74	G-377B	487.956	G-380B	209.542
G-374C	459.21	G-377C	486.042	G-380C	178.127
G-374D	458.1	G-377D	489.35	G-380D	193.095
G-374E	457.6	G-377E	496.679	G-380E	119.548
G-374F	457.6			G-380F	268.29
Total	2769.52		2450.75		1219.13
		3,669.88			
Exact	2770.0	3,670.0			

Simulated water surface elevations (Figure 37) vary from 15.80 ft NGVD in the Inflow Canal to 13.0 ft NGVD upstream of outflow structures. Central flow-way (Cell 2A and 2B) has lower water levels than Cells 1A, 1B and Cells 3A and 3B. Cells 3A and 3B have the smallest hydraulic gradient.

Specifically, the computed headwater (HW) and tailwater (TW) levels at major flow structures are as follows.

For Cell 1, G-374 A-F TW: 14.86 ft NGVD; G-375 A-F HW/TW: 14.47/13.50 ft NGVD; G-376 A-F HW: 13.34 ft NGVD.

For Cell 2, G-377 A-E TW: 14.56 ft NGVD; G-378 A-E HW/TW: 14.49/13.15 ft NGVD; G-379 A-E HW: 13.0 ft NGVD.

For Cell 3: G-380 A-F TW: 14.33 ft NGVD and G-381 HW: 13.78 ft NGVD.

The water depth distribution plot (Figure 38) shows predicted water depths varying from 2.5 ft to 5.5 ft in the marsh areas, water depths greater than 4.5 ft were shown as deep blue in the plot. The emergent Cells 1A, 2A and 3A have a depth of flow greater than 4.5 ft in most of the area. It should be noted that although the model simulation predicts depths greater than 4.5 ft in this scenario, the District operates the STAs to ensure depths of this type are avoided. In addition, the current operating protocol is to avoid the higher depths (3.0 to 4.5 ft) for more than 10 days, as they may be harmful to the health of the emergent treatment plants. Furthermore, the Design Peak Flow condition is the maximum flow for normal operation and it usually relates to big storm events. Precautious pre-storm drawdown and maintaining a low average water depth between storm events will help keep water depth within the design range.

The model simulated steady state flow, so information on duration cannot be provided. A new model run was made that used the computed Design Peak Flow steady state flow as initial condition and assumed no inflow and let the cells drain for 2 days. It was observed that computed water depth quickly decreased by -0.5 ft to -2.5 ft in the marsh areas. The draining of the cells after a major storm will therefore be a function of operational decision.

Velocity magnitude values (Figure 39) are under 0.1 ft/s in the marsh area and flow is relatively uniform. The nominal residence time is 6.5 days under Design Peak Flow.

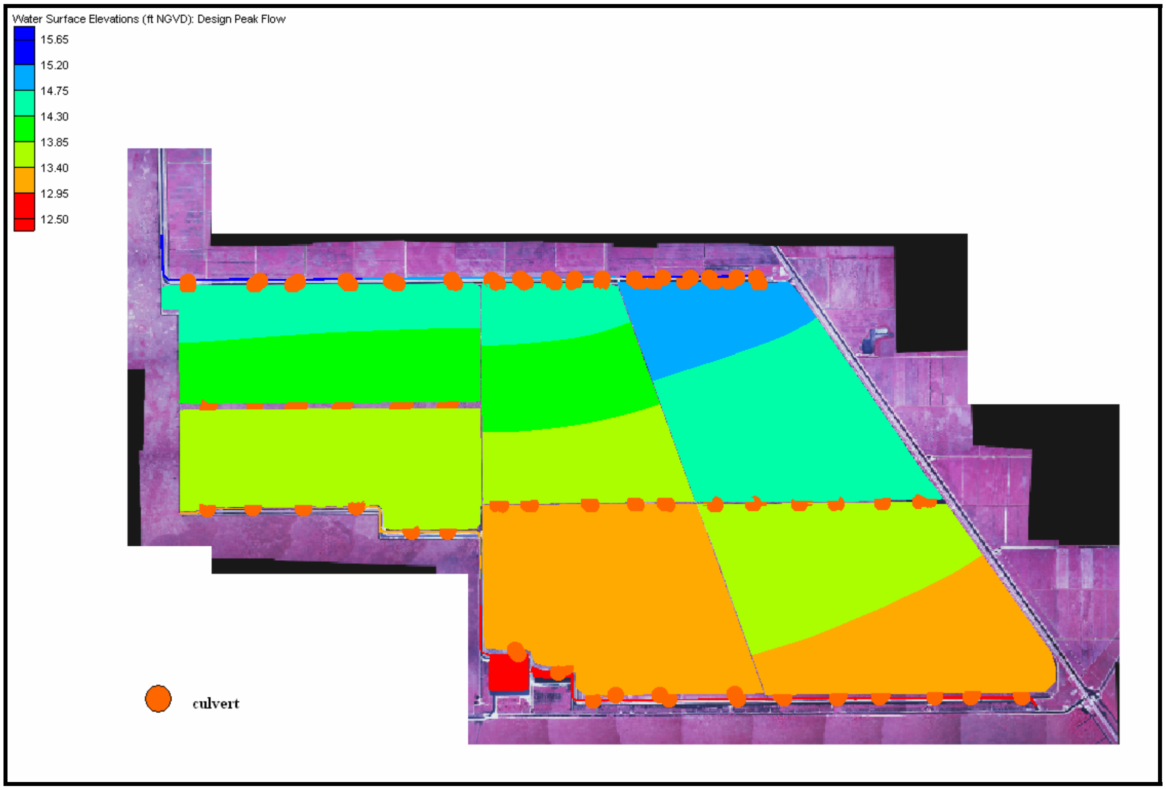

Figure 37: Water surface elevations (ft NGVD, Design Peak Flow)

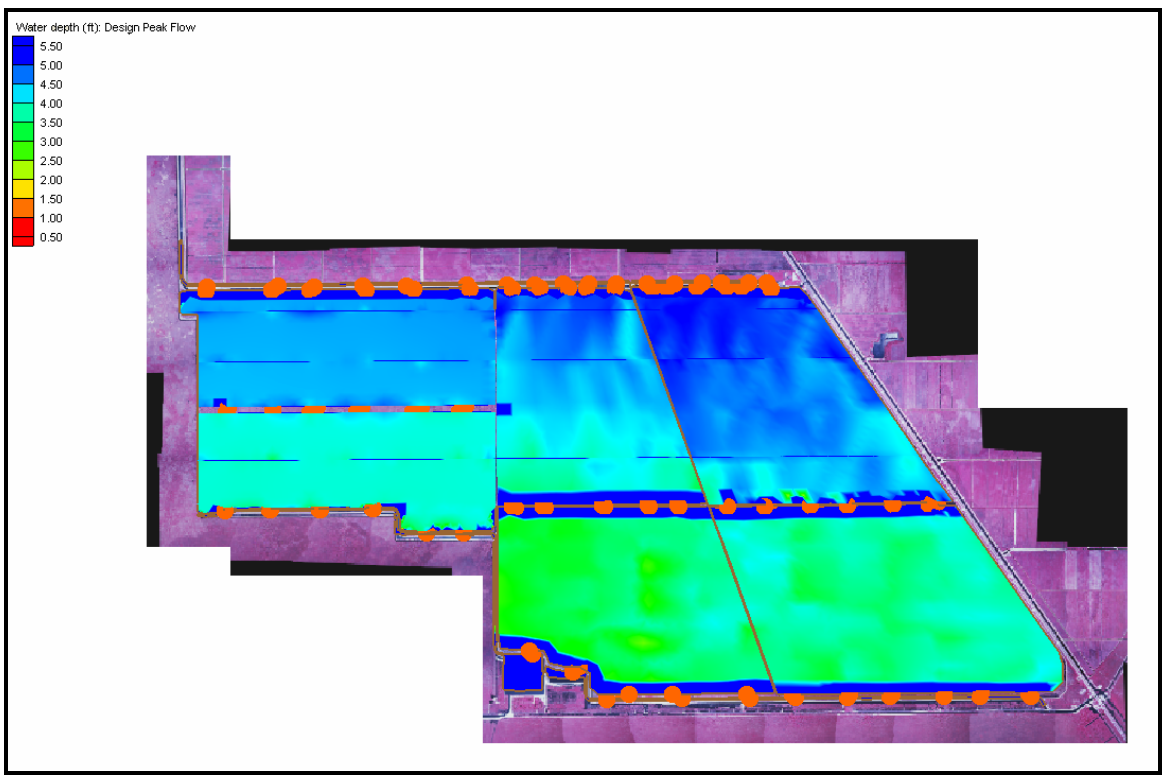

Figure 38: Distribution of water depth (ft, Design Peak Flow)

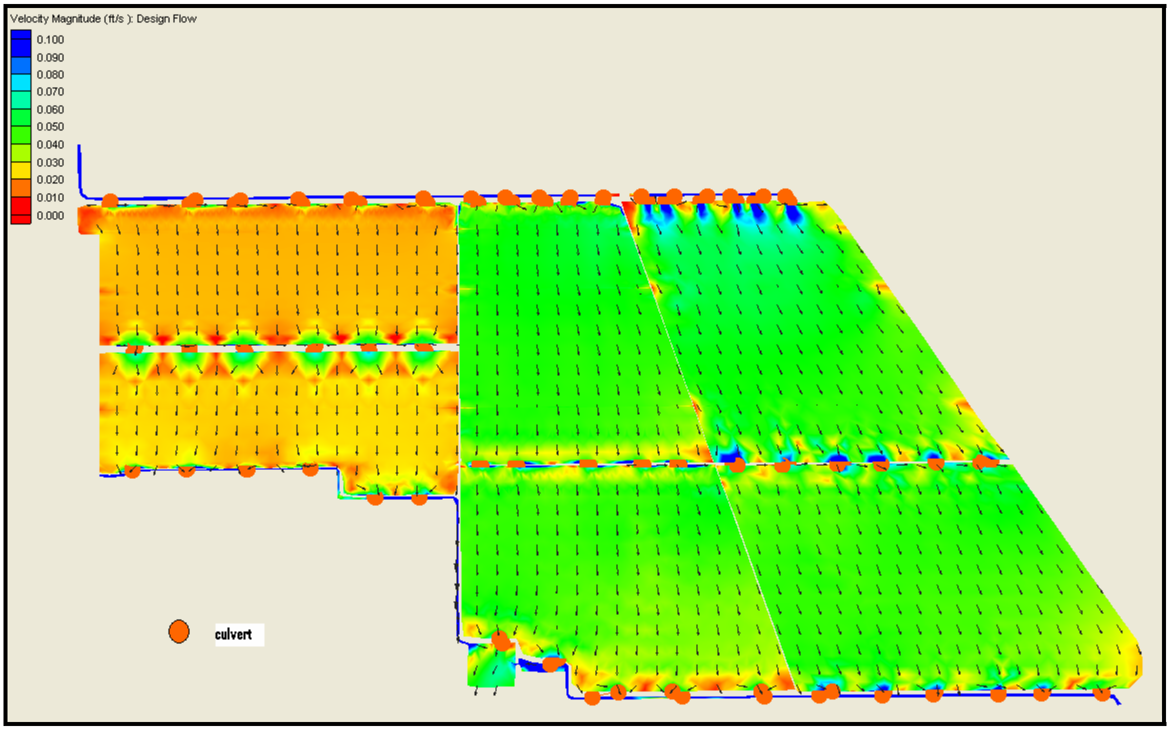

Figure 39: Velocity magnitude (fps, Design Peak Flow)

5.2 Low Flow

The Mean Annual Flow condition as defined in Burns & McDonnell (2000) was chosen as the Low Flow condition for this current modeling effort.

The mean annual inflow into Cell 1A is 398 cfs and the total inflow into western and central flow-ways (Cell 2A and Cell 3A) is 487 cfs (Burns & McDonnell, 2000). The total inflow of STA-3/4 is 885 cfs. The desired downstream water levels under Low Flow condition are 10.67, 11.12 and 11.01 ft NGVD for outflow structures G-376, G-377 and G-381 tailwater, respectively as defined in the STA-3/4 Operation Plan.

Under the Low Flow condition, evapotranspiration and seepage losses are likely to be important. A daily evaporation rate of 0.24 inch/day and an estimated seepage loss of 0.13 inch/day were applied to the whole STA-3/4 effective area in Low Flow simulation (adopted from (SFWMD, 2004a)). Since FLO2DH has no areal source/sink input option, volumetric rates were applied to a certain number of nodes uniformly distributed over the treatment cells. The seepage loss and ET volumetric rate is about 29% of the total inflow (885 cfs).

Simulation results for distribution of water surface, water depth and velocity magnitude are shown in Figures 40-42.

Predicted water depths range from 0.46 ft to 2.5 ft in the upstream emergent treatment cells, and from 0.46 ft to 1.8 ft in the downstream SAV dominant treatment cells. It should be noted that small forward-pumping stations are currently being installed in each of the three flow-ways that will allow pumping of water from the upstream emergent marsh cells to increase water levels in the downstream SAV cells if needed during extended periods of low flow.

The velocity magnitude plot indicates a velocity magnitude of 0.0 to 0.03 ft/s in the marsh areas. This is about 50% lower than in the Design Flow condition.

The nominal residence time based on Low Flow simulation results is 21.9 days for STA-3/4 as a whole.

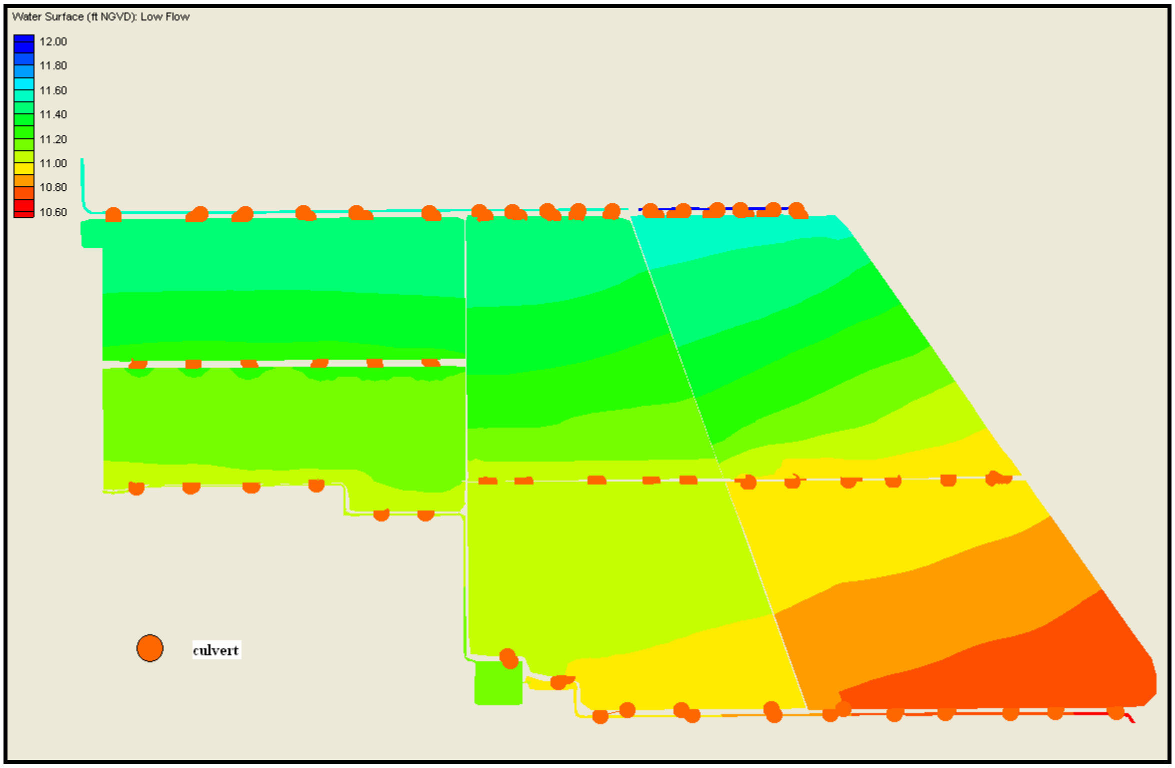

Figure 40: Water Surface Elevations (ft NGVD): Low Flow

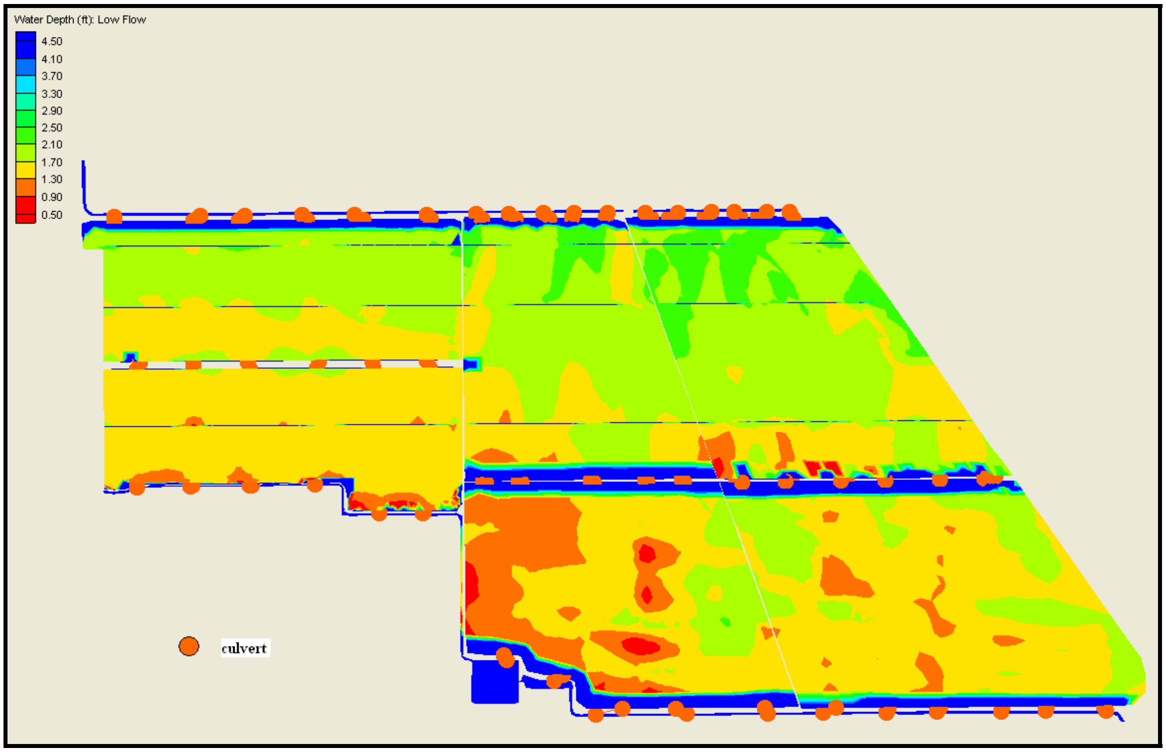

Figure 41: Water Depth Distribution (ft): Low Flow

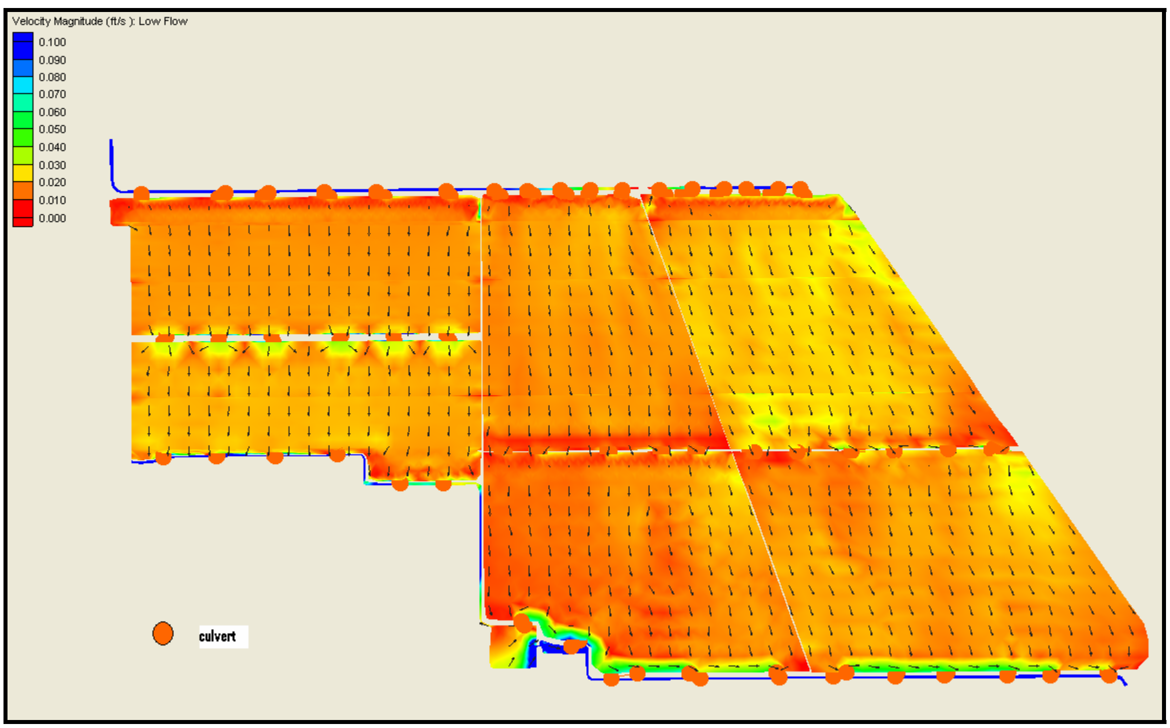

Figure 42: Velocity Magnitude (ft/s): Low Flow

5.3 High Flow

The Standard Project Storm (SPS) as defined in the STA-3/4 Operation Plan is simulated as the High Flow condition.

Direct rainfall on the STA is assumed as a maximum 3-day precipitation depth of 36 inches. No temporal and spatial distribution information is available, therefore, the rainfall distribution is assumed to be uniform. Since FLO2DH has no direct input option for rainfall, the volumetric rainfall rate was distributed as point sources across the cells.

STA-3/4 is assumed to be under Design Peak Flow condition before the SPS storm. The downstream boundary conditions are specified constant water levels as defined in the STA-3/4 Operation Plan. Under the Standard Project Storm, the tailwater levels for outflow structures G-376, G-379 and G-381 will be 15.3, 15.6 and 16.1 ft NGVD, respectively.

A transient simulation with the simulated Design Peak Flow as initial condition was performed for 240 hours and peak water levels were reached at the end of the 72 hours when rainfall stops.

The rising and falling of stages in STA-3/4 during the SPS storm event is demonstrated in Figure 43. Tailwater levels at inflow structures G-374, G-377 and G-380 reach peak stages ranging from about 16.8 to 17.6 ft NGVD.

Water depth during a SPS storm event exceeds the maximum depth of 4.5 ft (peak water depth in the marsh areas are from 5.8 ft to 8.5 ft) in the upstream cells 1A, 2A and 3A and some of the downstream cells (Figure 44). It is detrimental to wetland treatment plants if this extends for more than 10 days. On the other hand, velocity magnitude in the marsh area is low (0.01 to 0.06 ft/s) (Figure 45). Peak water surface elevations range from 15.5 to 18.4 ft NGVD (Figure 46).

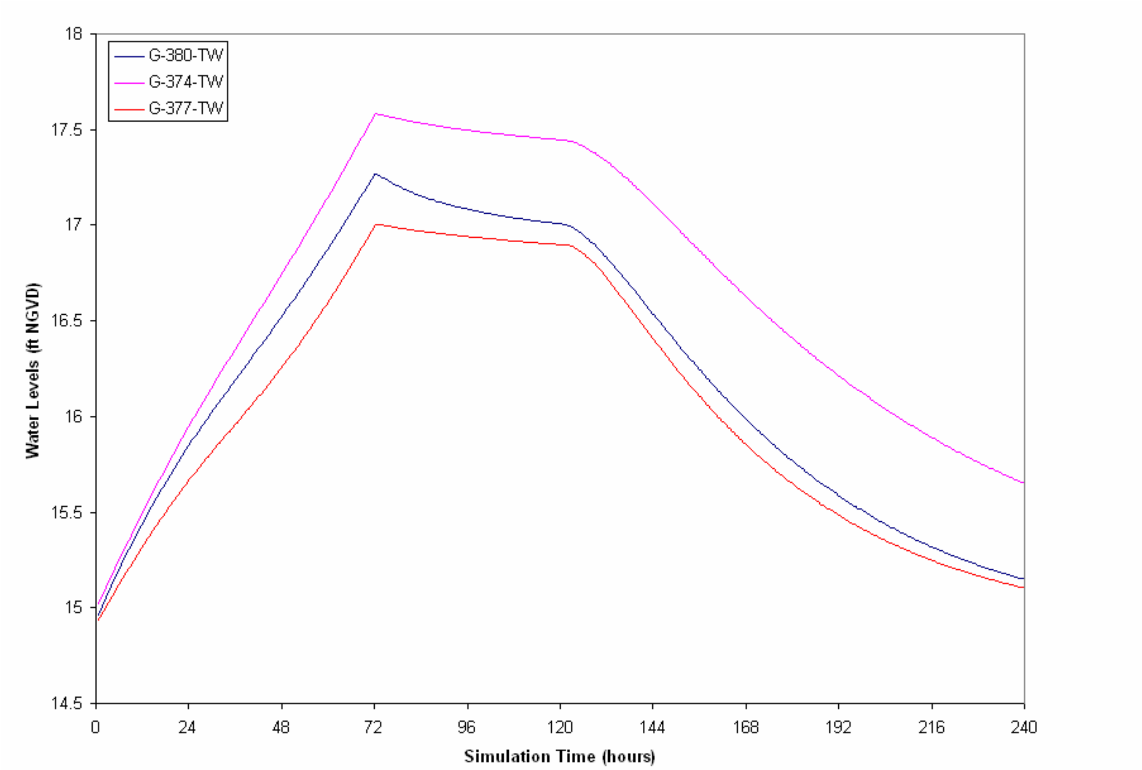

Figure 43: Stage Hydrograph during SPS storm (Inflow Structures Tailwater levels)

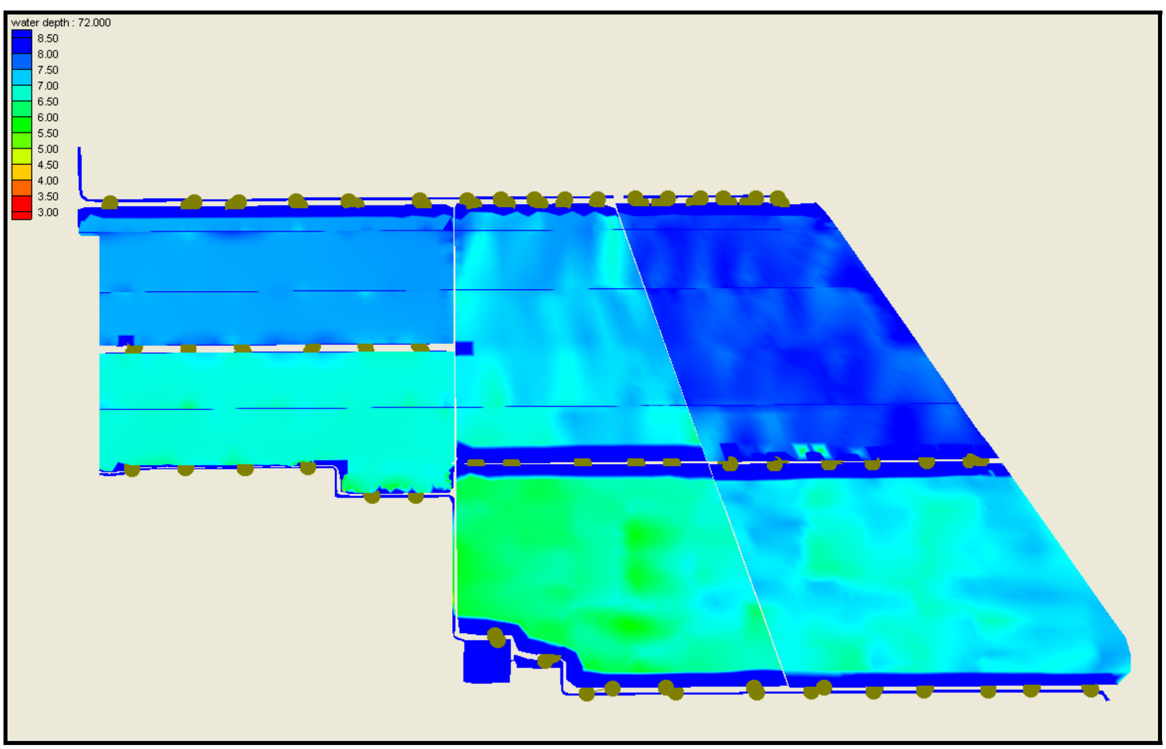

Figure 44: Water Depth Distribution (ft) at Peak Water Levels (High Flow)

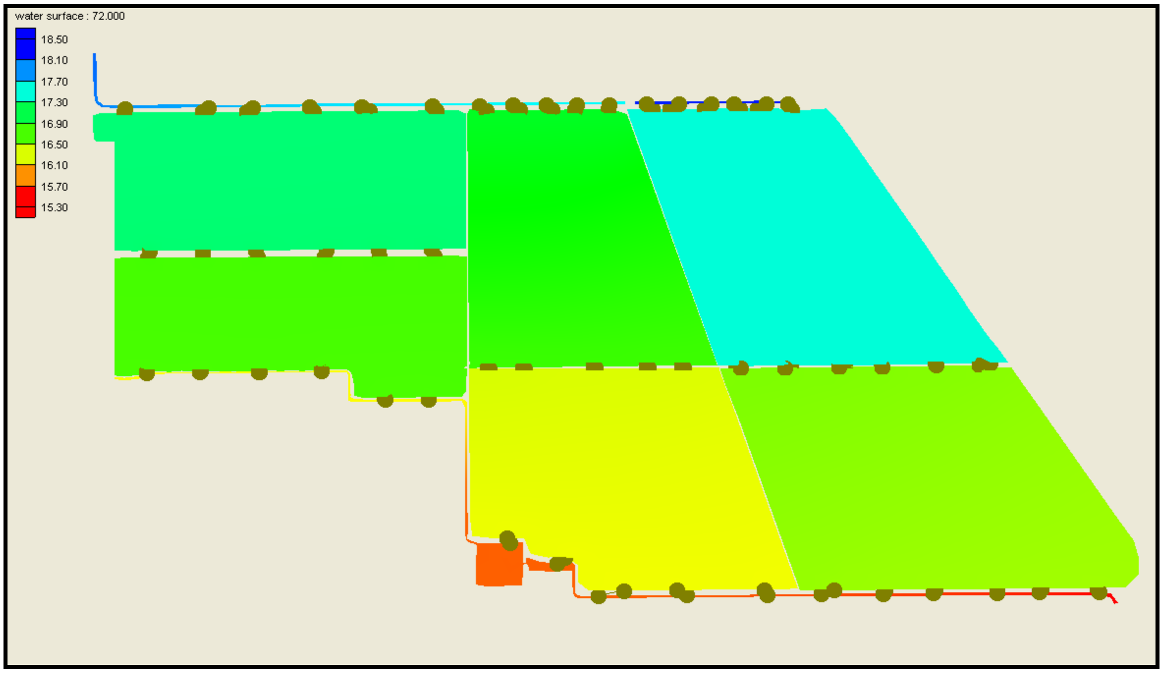

Figure 45: Peak Water Surface Elevations (ft NGVD) (High Flow)

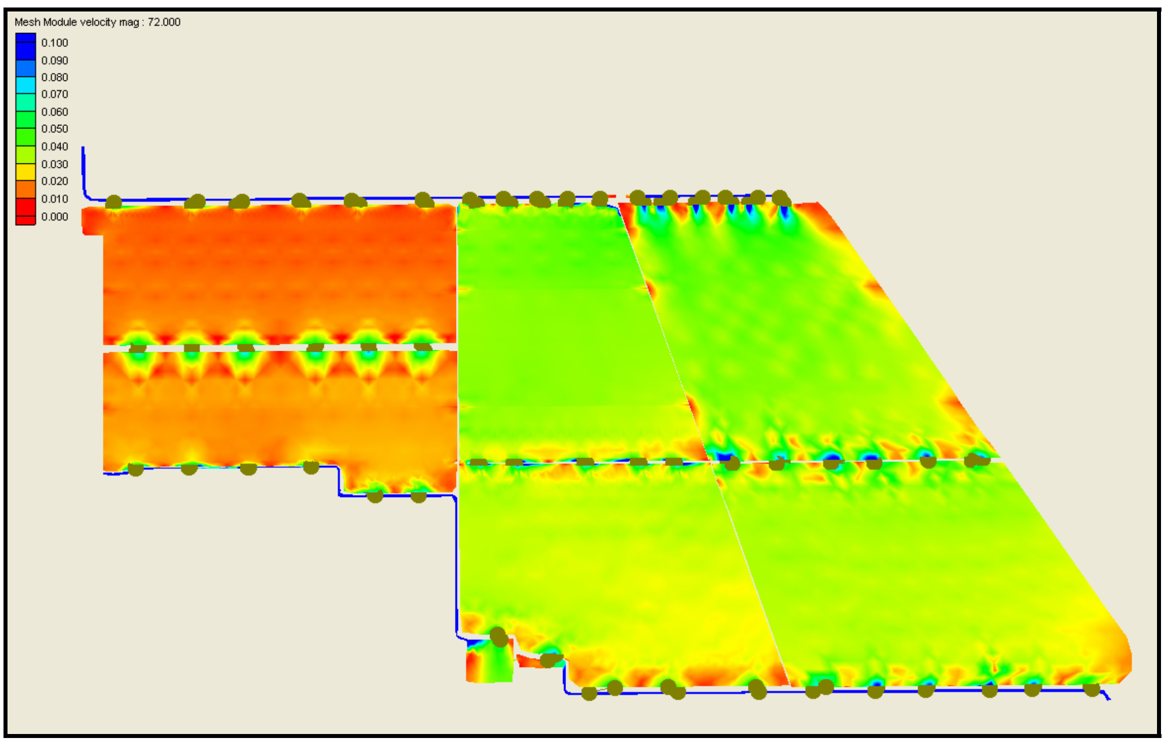

Figure 46: Velocity Magnitude (fps) Plot at Peak Stage Level (High Flow)

6. Summary and Conclusions

Basic model data and information from previous STA-3/4 single cell 2-D steady flow models were used to develop a new STA-3/4 2-D linked cells model integrating new vegetation information, flow structures and other features. Model calibration and verification were conducted to better estimate Manning's roughness coefficients for STA-3/4 vegetations. Features of the new model include: (1) explicit presentation of culverts; (2) all STA-3/4 hydrologic components (inflow/discharge canals and treatment cells) are linked together and (3) model calibration with historical data.

The new 2-D model was used to simulate several flow scenarios for the STA-3/4 enhanced configuration. Simulated velocity distribution is favorable in the marsh areas, the velocity magnitude in the marsh areas are smaller than 0.1 ft/s. On the other hand, water depth distribution needs more operational involvements. Pre-storm drawdown and after-storm draining of the cells may be necessary to maintain a long-term average water depth of 1.25 ft in the marsh areas.

Topographic data from previous modeling studies and assumptions on vegetation distribution were used to build the new linked cells model. It is recommended that the model be tested and updated with new structure flow ratings and new vegetation information as this information becomes available in the future.

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